PERMANENT WAY

AND

POINTS & CROSSINGS

FOR THE

6″ GAUGE

BY

K. N. SALKADE.

SECOND EDITION.

Permanent Way

AND

Points and Crossings

WITH

Explanatory Notes & Formulae for the 5′ - 6″ Gauge

BY

K. N. SALKADE,

Permanent Way Inspector,

G. I. P. Railway, Burhanpur.

SECOND EDITION, REVISED AND ENLARGED WITH 30 ILLUSTRATIONS (1928).

Published by K. N. Salkade at Burhanpur, Dist. Nimar, C.P.

PRINTED AT THE EXAMINER PRESS.

1928.

This small book is dedicated
with kind permission
in token of respect and gratitude

to

P. E. KEENE, Esquire,
M.I.C.E.,

Late Chief Engineer, G. I. P. Ry.,
Bombay,

by

K. N. Salkade,

The Author.

Some opinions of eminent Engineers and Principals of Colleges of Civil Engineering on the second edition of the Book.

(1) J. Neilson Esquire, Senior Government Inspector of Railways, Circle No. 6, Bombay.

"I beg to acknowledge with thanks the receipt of your book on Permanent Way and Points and Crossings. The information contained therein will certainly be of advantage to apprentices and staff starting their careers on open line."

(2) W. A. Buyers, Esqr., Senior Government Inspector of Railways, Circle No. 5, Bombay.

"A cursory glance through the book shows that there is a lot of useful matter in it which must be valuable not only to the young apprentices learning their work but to the experienced platelayer himself."

(3) Chief Engineer, Burma Railways, Rangoon. (2-3 1928.)

"I beg to thank you very much for your hand book on 'Permanent way and Points and Crossings.' It seems a very useful work and full of valuable information."

(4) Chief Engineer, North Western Railway, Lahore. (23-2-1928.)

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(5) Chief Engineer, B. B. & C. I. Railway, Bombay. (19-3-1928.)

> "I think your hand book on P. Way and Points and Crossings contains a lot of information which should be useful to those engaged on Permanent Way maintenance."

(6) E. Fraser, Esqr., A. M. I. C. E., Offg. Chief Engineer, G. I. P. Railway, Bombay.

> "Your book 'Permanent Way & Points and Crossings' appears from a preliminary perusal to serve the useful purpose for which it is intended and I congratulate you on your enterprise in producing so handy a volume."

(7) G. E. Hooper, Esqr., Chief Engineer, Way and Works. Ceylon Government Railway, Colombo.

> "I have the honour to inform you that I have read your book which contains much valuable information."

(8) Lt.-Col. E. W. C. Sandes, Esqr., D. S. O., M. C., R. E., Principal, Thomson College, Roorki.

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(9) Principal, Engineering College, Benares Hindu University, Benares. (5-3-1928).

" I am obliged to you for sending me a copy of your book on 'Points and Crossings' which is a very useful book to young Engineers especially to those who have not the benefit of any training in an Engineering College. I must congratulate you also on the general get-up of the book. Wishing you every success."

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(11) C. Tedman, Esqr., M. C., A. M. I. C. E., Dy. Chief Engineer, G. I. P. Ry., Bombay.

"I duly received a copy of your book and have to thank you for it. I have read a good deal of your book and can repeat my opinion on the first edition of the book. It should undoubtedly prove very useful to all P. W. Inspectors and especially so to apprentice platelayers."

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"I have to acknowledge receipt of your book 'Points & Crossings' with many thanks. It appears to contain a good deal of useful information and will be added to my office library."

(13) F. G. Langdon, Esqr., A. M. I. C. E., Divisional Engineer, G. I. P. Ry., Nagpur.

"Many thanks for your latest book on 'Points and Crossings.' I know of no other book of its kind which puts everything needed to the practical man so clearly and simply and feel sure it must fill a long-felt want. May it bring you the pecuniary success it deserves."

(14) A. McInerny, Esqr., District Engineer, G. I. P. Ry., Manmad.

I have received a copy of your hand book 'Permanent Way and Points & Crossings' for which I thank you. It appears to me to be a practical summary of permanent way methods and should be of value to beginners and handy for more experienced men for occasional reference."

J. Temple Esqr., Divisional Engineer, G. I. P. Jubbulpore.

' I thank you for your book on Points and Crossings. The revised edition seems most comprehensive and I am sure the Sub P. W. Inspectors and P. W. Inspectors will find the contents most useful to them."

(16) C. J. Keelan, Esqr., Divisional Engineer, G. I. P. Ry., Poona.

" I thank you for the copy of your book on P. Way and Points and Crossings. It should be found most useful to those engaged on P. Way, especially to Sub-Inspectors and others aspiring to become Inspectors.""

(17) A. Orr, Esqr., B. Sc.. A. M. I. C. E., Resident Engineer, Relaying, G. I. P. Ry., Khandwa.

" Thanks very much for the copy of your book on Permanent Way which I have received and which I read with interest. The book contains much information which should be very useful to all those engaged on permanent way work and I think you deserve much credit for the way in which the information has been compiled."

(18) K. C. Bakhle, Esqr., B. SC. (London), Resident Engineer, G. I. P. Ry., Parel.

" I have to thank you for the copy of your hand book on Permanent Way and Points and Crossings. It is an excellent publication and should be of great use to apprentice platelayers, sub-inspectors, etc."

(19) Chief Engineer, South Indian Ry., Trichinopoly. (3-4-28.)

" In thanking you for sending me a copy of your book entitled 'Permanent Way and Points and Crossings,' I have to state that the book has been perused with interest. I am of opinion that Permanent Way Inspectors and Sub-Inspectors would find matter of interest and utility in the book and I think if the price is low, it might command a good sale in India."

Some opinions of Eminent Engineers on the first edition of the "Notes on Points and Crossings."

(1) A. B. Strange, Esqr., Chief Engineer, M. & S. M. Ry., Madras.

"Many thanks for the interesting little book you have been so good as to send me. I have been certainly struck by the clearness and simplicity of the methods employed in the various demonstrations."

(2) P. E. Keene, Esqr., M. I. C. E., Chief Engineer, G. I. P. Ry., Bombay.

"I am very much obliged to you for sending me a copy of your small work on Points and Crossings, which I have perused with interest. I am quite sure that a small work of this kind will be found most useful by all Sub-Inspectors and Time-keepers and I congratulate you on your production."

(3) R. V. Symons, Esqr., Superintending Engineer, G. I. P. Ry., Bombay.

"I beg to acknowledge with thanks your book of Notes on Points and Crossings. There are many useful practical hints in the book and it should be useful to Apprentices and Time-keepers."

(4) W. G. Barnett, Esqr., District Engineer, G. I. P. Ry., Poona.

"I am much obliged to you for sending me a copy of your little book on Points and Crossings. I think it is very creditable of you to have undertaken the collection of the information."

(5) N. P. Roe, Esqr., District Engineer, G. I. P. Ry., Manmad.

"I have received your book on Points and Crossings. I think the book should be of considerable assistance to many of the Engineering Staff. The information you give appears to fulfil a want felt by many of our Inspectors who are not conversant with sufficient Mathematics to follow involved formulæ, the result being that they often adopt the practice of putting Points and Crossings in by eye if left to themselves. I therefore wish your book the success it merits."

(6) E. R. Dangerfield, Esqr., District Engineer, G. I. P. Ry., Jhansi.

"I am much obliged to you for the small book on Points and Crossings you have sent me. I consider the book will be of great use to P. Way Apprentices, Sub-Inspectors and others of that class."

(7) C. D. Swinhoe, Esqr., District Engineer, G. I. P. Ry., Bina.

"I have to acknowledge with thanks the receipt of your little book on Points and Crossings. From what I have seen of it, it would appear to be a very useful collection of hints and tips put up in a handy form for carrying about on the line. It should thus be a useful companion for both Engineers and P. W. Inspectors and especially for Apprentices and those who have not the advantage of long years of experience, to whom it should be of the greatest assistance."

(8) C. Tedman, Esqr., M.C., A.M.I.C.E, District Engineer, G. I. P. Ry., Nagpur.

"I beg to thank you for your book on Points and Crossings which appears to be a useful compilation. I wish you success."

(9) A. Bremner, Esqr., District Engineer, G.I.P. Ry., Jubbulpore.

"Thanks for the book on Points and Crossings you have been so kind as to send me. I have glanced at it and saw one or two hints which I am sure will be useful to Inspectors. I hope you will derive some benefit from it."

(10) A. F. Campbell, Esqr., Resident Engineer, G.I.P. Ry., Bhusaval.

" I acknowledge with thanks the little book which you have sent me. It would seem to me to be a most valuable companion for those who are not acquainted with the Mathematics of this section of a Railway man's work. I am convinced the book will be of great use to beginners and even those who are more advanced in this profession."

(11) M. Elliot-Cooper, Esqr., Resident Engineer, G. I. P. Ry., Bhusaval.

" I have read through your book on Points and Crossings. There are a useful collection of facts and formulæ ; it should be of assistance to the Permanent Way Staff, its size making it especially handy for reference on the ground."

(12) R. Roche, Esqr., A. C. G. I., Resident Engineer, G. I. P. Ry., Jalgaon.

" I have perused your book on Points and Crossings and I think it will be of assistance to those occupied on that work. I wish it all success."

(13) J. H. Morris, Esqr., Resident Engineer, G. I. P. Ry., Ahmednagar.

" I have read your book on Points and Crossings and am sure Amateurs, Apprentice-Platelayers, Time-keepers etc. will find it very useful in their work."

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I. List of Illustrations—(*contd.*)

II. Preface to the Second Edition.

The success which attended the publication of the "Notes on Points and Crossings" for the 5'-6" Gauge has encouraged the Author to issue a second edition of the work as the first one is all out of print and there is still a persistent demand for the same.

2. This edition has been largely increased and the whole work has been carefully revised and corrected where necessary. The added matter consists of several new articles on points and crossings, a new chapter on G. I. P. Ry. practice, another one on curves and a revised schedule of Standard Dimensions in force and recommended. The miscellaneous chapter has also been enlarged, and re-arranged with a list of elementary geometrical definitions and useful rules on mensuration which a Plate-layer usually comes across in learning the theory of his work and in doing this, all technicalities which might confuse an amateur are avoided.

3. Amongst the Authors I have consulted, are Cole, Jones, Pudma Naben, Karamchand, and the Author of the G. I. P. Ry. Hand-book for Engineers to all of whom, I tender my best thanks. My thanks are also due to Mr. H. Yesonath, B. E., for the help he gave me in making out the diagrams as required.

4. I also offer my most grateful thanks to P. E. Keene, Esq., M. I. C. E., Late Chief Engineer, G. I. P. Ry., and to C. Tedman, Esq., M. C., A. M. I. C. E., Dy. Chief Engineer, G. I. P. Ry., for the valuable criticism and suggestions they offered on the first edition and which have been attended to in this issue.

5. The value of this small book lies in the feature that it does not take the student up at an advanced point assuming that he knows a great deal of the subject but teaches him *ab initio* all that is necessary to learn in the theory of Points and Crossings and it is a matter of great personal satisfaction to me that the first edition of the book met with general approval of eminent Engineers on the G. I. P. and other Indian Railways as will be seen from the few extracts of opinions published in the beginning and I hope that this revised edition will be found of even greater value to all interested in the Permanent Way work.

6. All suggestions and criticism will be most thankfully received.

K. N. SALKADE.

Burhanpur, January 1928.

CHAPTER I.

Points and Crossings.

Explanation of Signs, Symbols, Terms and Definitions used.

1. Explanation of symbols.

C = Cord.
G = Gauge of road =5′-6″
D = Distance between centre of tracks.
N = Number of crossing.
R = Radius of crossing.
L = Lead of crossing.
CL = Curve lead.
SL = Switch lead.
TP = Tangent point.
TS = Toe of switch.
HS = Heel of switch.
TNC = Theoretical Nose of crossing.
LT = Length of Turn-out or cross-over tangent to tangent.
CT = Distance from tangent point to the reversing point of a Turn-out and a cross-over.
ST = The straight track between reverse curves.
RP = Reversing point.
NC = Visible or blunt Nose of crossing.
S = Spread of crossing.
V = Versine of curve.
W = Width of top of rail.

2. Definitions of Permanent Way.

1. **Permanent Way**—Road completely equipped with rails, sleepers and fastenings on which Railway Vehicles run. (The term permanent way is used to distinguish the finished Railway from the temporary tram roads used during the construction of the line, for making embankments and for carrying materials for the Railway from one place to another).

2. **Gauge**—The clear distance from running edge to running edge of the top tables of rails laid parallel. The word gauge also applies to the instrument by which that distance is measured.

3. **Points**—The movable rails by means of which trains are diverted from one road to another.

4. **Trailing and Facing Points**—Points are either facing or trailing according to the direction from which they are approached by trains. When a train approaches the points from their heel, they are called trailing points but when they are approached from their toe or the thin end, they are called facing points.

5. **Gradient**—The rate of slope of the ground ascending or descending of a rail road.

6. **Ruling gradient**—The steepest rate of inclination which prevails generally on the line, being exceeded only on exceptional portions.

7. **Gradient-Post**—Post fixed at every change of grade showing the rate of slope.

8. **Cant**—The inward inclination of one rail to the other usually 1 in 20.

9. **Elevation or super-elevation**—The height of the outer rail above the level of the inner rail on any curve.

10. **Crossing**—The point at which two sets of rails cross one another.

11. **Diamond Crossing**—A permanently fixed arrangement of tongue rails where one track crosses another, so arranged that a vehicle passing on one of the lines that cross, is enabled to keep to its own line.

12. **Switch Diamond crossing**—Similar arrangement of one track crossing another as in ordinary diamonds but with movable switch rails.

13. **Triangle**—A combination of three sets of points and crossings laid in the form of a triangle and situated with the main line

in a way to allow engines or whole trains if necessary to be reversed to run engine foremost.

14. **Turn-table**—A circular table on a central pivot supported by wheels at the circumference running on circular rails used for turning around engines.

15. **Tangent point**—The point from which a curve commences. This is also called the initial point, theoretical point of switch or springing of curve.

16. **Curve lead**—The distance from tangent point to theoretical nose of crossing measured along the straight.

17. **Switch lead**—The distance from tangent point to heel of switch measured along the straight.

18. **Lead of crossing**—The distance from theoretical nose of crossing to heel of switch measured along the straight.

19. **Theoretical nose of crossing**—The point of intersection of the gauge lines and from which all measurements are made.

20. **Nose of crossing**—The blunt, or visible nose of crossing.

21. **Angle of crossing**—The acute angle formed at the intersection of the rails.

22. **Radius of crossing**—The radius of the curve of the gauge line of one of the intersecting rails, the other being straight.

23. **Clearance**—The clearance at heel of switch is the distance from inside edge of stock rail to inside edge of switch rail, in other words, the gap between the stock and the switch plus the width of the head of the switch rail.

24. **Cross or Transverse sleepers**—Baulks of timber generally rectangular in section placed cross-wise to the rails. There are also iron and steel sleepers.

25. **Longitudinal sleepers or timbers**—Baulks of timber laid beneath and parallel to the rails to give them a continuous support.

26. **Check rail**—An extra rail placed parallel to the inner rail of track to relieve it from the sideways pressure of the wheels.

27. **Reverse curve**—A reverse curve is one formed by two curves turning in opposite directions and meeting tangent to each other. Two curves turning in opposite directions but having a piece of tangent between them do not constitute a reverse curve although they are commonly called so.

28. **Compound curve**—A compound curve is formed where two or more circular curves having different radii and turning in the same direction meet tangent to each other or one another in succession.

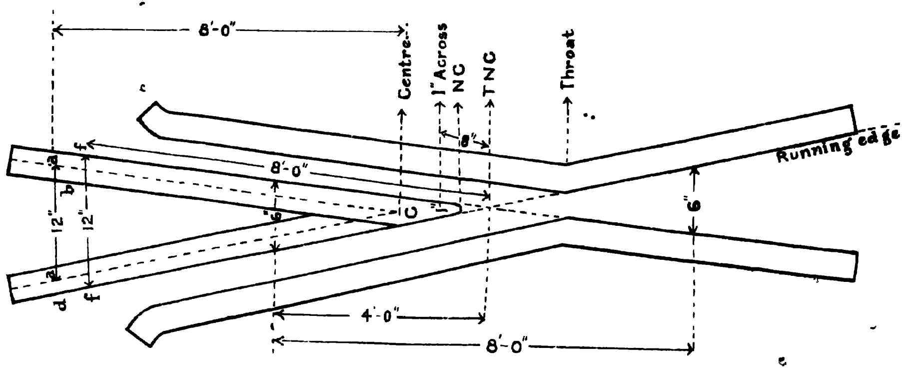
29. **Traverser.**—A low frame dwarf carriage about 1 foot high, mounted on small wheels which run on rails laid at right angles to the direction of the tracks by means of which carriages are transferred, one at a time, to and from parallel roads, without the necessity of shunting.

3. TERMS IN GENERAL USE.

1. Embankment, fill, bank and formation means the same.
2. Road and track means the same.
3. Broad gauge and 5′-6″ means the same.
4. Metre gauge and 3′-3⅜″ means the same.
5. Slack gauge and widening of gauge means the same.
6. Cross and transverse sleeper means the same.
7. D. H. or double headed rail means the same.
8. B. H. or bull headed rail means the same.
9. F. F. rail, flat footed rail, flat bottomed rail, flanged rail and Vignoles' rail means the same.
10. Check rail, guard rail, guide rail and counter rail means the same.
11. Curving rail and bending rail means the same.
12. Canting and tilting of rail means the same.
13. Even and square joints means the same.
14. Staggered, broken and uneven joints means the same.
15. S curve, serpentine curve and reverse curve means the same.

16. Cant, elevation and Super-elevation means the same.
17. Toe of switch and nose of switch means the same.
18. Stock rail, main rail and back rail means the same.
19. Frog and crossing means the same.

— —— ——



Common 1 in 8 crossing showing how to take measurements

Diagram No. 1.

CHAPTER II.

Points and Crossings.

MEASUREMENTS OF CROSSINGS.

Diagram No. 1.

A. Diagram 1 shows a common 1 in 8 crossing and the method of its measurements.

In the diagram (1) point TNC is the theoretical point of crossing. It is the intersection of the gauge sides of the point rails and from it, all measurements are made. NC is the actual nose, commonly called the blunt nose of the crossing and is rounded off. Centre of crossing C is the place where the face of crossing is the same width as the top flange of one rail and where the inter-sections of two lines drawn along the centre line of the two rails attached to the crossing would meet if extended on the crossing face.

B. To find the centre of any crossing :—

Measure the crossing across where it is exactly the width of the top flange of one rail. The centre point at this width of any crossing is the centre required.

C. To find the theoretical point of any crossing:—

(*a*) Place a straight-edge on one side of the crossing face or gauge side and let

it project a foot or so beyond the nose and on the opposite side of the crossing hold a string (both the string and the straight edge must touch the edges of the crossing all the way along) and the point where the string crosses (intersects or cuts) the straight-edge, is the theoretical point of that crossing.

(*b*) If a straight edge is not available, hold two strings one on each side of the crossing face (both strings must touch the running edges of the crossing all the way along) and let them project a foot or so beyond the nose. The point where the two strings will intersect or cross each other, is the theoretical point of that crossing.

D. To find the distance from actual nose of crossing (this is also called the blunt nose) to the theoretical point :—

Multiply the thickness of nose by the number of crossing.

Example :—

The number of crossing is 1 in 8 and the thickness of nose is $\frac{3}{4}$ inch.

therefore $8 \times \frac{3}{4} = 6$ inches, distance from actual nose of crossing to theoretical nose of crossing.

E. Practical methods to find out the number, lead or spread of any crossing :—*Diagram 1.*

(*a*) Measure from the theoretical point of the crossing to where it is one inch wide across. As many inches as it is between these two points, so many feet is the spread or number of that crossing.

(*b*) Measure from the centre C of the crossing (see diagram 1) to where the two rails attached to the crossing (*aa*) is 1 foot across, or where from the inner edge of one rail to the outer edge of the other (*db*) the distance is one foot, the intervals between the centre of the crossing and either of these points *aa* or *db* are the spreads or the numbers of that crossing in feet.

(*c*) Measure from the theoretical point of the crossing to where the two rails attached to it from outer edge of one rail to the outer edge of the other is one foot across *ff* the distance between the two points *f* and TNC is the spread or number of that crossing in feet.

(*d*) Measure from the theoretical point to where the face of the crossing is 6 inches wide, multiply this distance by

2 and the result will be the spread or number of that crossing in feet.

(*e*) Measure from where the face of the crossing is one inch wide across tc where the same is two inches wide. As many inches as it is between these two points, so many feet is the spread or number of that crossing.

(*f*) Divide the length of the crossing ii inches by the distances from running edge to running edge at both ends of the crossing (in inches) added together. The quotient will be the number of that crossing in feet.

(*g*) Find out the places where the face of the crossing is 6 inches wide on either side. The distance between these two places measured along the crossing is the number or spread of that crossing in feet.

Note.—Numbers of crossings are always shown on the crossing chairs and it is very easy to identify them. The above rules will be found very useful to find the number of crossings when they cannot be identified by the numbers on the chairs due to being smeared with oil and dust.

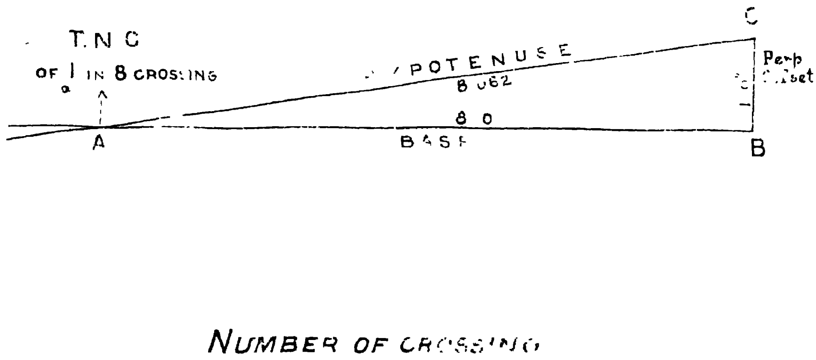

T. N C
OF 1 IN 8 CROSSING
A
B
C
POTENUSE
8 062
8 0
BASE
Perp
NUMBER OF CROSSING

DIAGRAM No 2.

5. NUMBER OF CROSSING.

Diagram No. 2.

When we say a 1 in 8 crossing, we mean 1 foot perpendicular offset for 8 feet base line from the nose of crossing *i. e.* one foot of spread in 8 feet length. In diagram 2, a 1 in 8 crossing is represented by a right-angled triangle in which A is the theoretical nose of the crossing, perpendicular offset is 1 foot and base is 8 feet. The Hypotenuse is $= \sqrt{8^2 + 1^2} = 8{\cdot}062$ feet.

Ordinarily when a man, who has not had the advantage of learning either geometry or trigonometry, comes across geometrical or trigonometrical expressions, he fails to understand their meaning. It is for the advantage of such men that I give below a few, only a few out of many, geometrical and trigonometrical equivalents which they should try to understand thoroughly as they will help a great deal in solving all the problems connected with the points and crossings.

Geometrical and trigonometrical equivalents :—

(1) Base

$$= \sqrt{\text{Hypotenuse}^2 - \text{Perpendicular}^2}$$

(2) Perpendicular

$$= \sqrt{\text{Hypotenuse}^2 - \text{Base}^2}$$

(3) Hypotenuse

$$= \sqrt{\text{Base}^2 + \text{Perpendicular}^2} \quad ;$$

(4) Versine

$$= \frac{\text{Hypotenuse} - \text{Base}}{\text{Hypotenuse}} \quad ;$$

(5) Tangent *a*

$$= \frac{\text{Perpendicular}}{\text{Base}} \quad ;$$

(6) Co-tangent *a*

$$= \frac{\text{Base}}{\text{Perpendicular}} \quad ,$$

(7) Sine *a* Hypotenuse

$$= \frac{\text{Perpendicular}}{\text{Hypotenuse}} \quad .$$

Now that we know the values and relations of the above trigonometrical equivalents, it will be easier to follow Diagram No. 2. In this diagram, the right angled triangle ABC represents a 1 in 8 crossing of which AB is the base, BC the perpendicular offset and AC the hypotenuse. When one side is known, find out the others :—

(1) To find out the hypotenuse :—

$$\text{Hypotenuse} = \sqrt{\text{Base}^2 + \text{Perpendicular}^2}$$

$$= \sqrt{8^2 + 1^2} = \sqrt{64 + 1} = 8{\cdot}062$$

Hypotenuse.

(2) To find out the perpendicular offset when base is known :—

'Multiply the base with tangent a'

$$\text{Tangent } a = \frac{\text{Perpendicular}}{\text{Base}} = \frac{1}{8}.$$

$$\times \frac{1}{8} \quad 1 \text{ Perpendicular offset.}$$

(3) To find out the perpendicular offset when hypotenuse is known :—

'Multiply the hypotenuse with sine a hypotenuse.'

$$\text{Sine } a \text{ hypotenuse} = \frac{\text{Perpendicular}}{\text{Hypotenuse}} \quad \frac{1}{8\cdot062}$$

$$\frac{8\cdot062}{1} \times \frac{1}{8\cdot062} = 1 \text{ Perpendicular offset.}$$

(4) To find out the base when perpendicular offset is known :—

'Multiply the perpendicular offset with co-tangent a.'

$$\text{Co-tangent } a = \frac{\text{Base}}{\text{Perp. offset,}} = \frac{8}{1}.$$

$$\frac{1}{1} \times \frac{8}{1} = \quad 8 = \text{Base.}$$

There are other equivalents such as co-sine, co-versed sine, secant, co-secant which, although not very difficult, I shall not deal with as we need the application of only those given above. For values of those not dealt with here, see properties of a right-angled triangle under article 41 (10) Mensuration.

6. NOMENCLATURE OF SWITCHES AND CROSSINGS.

Diagram No. 3.

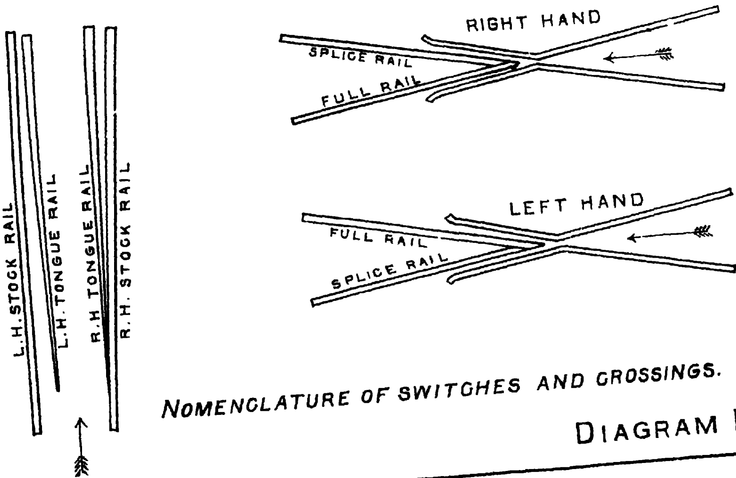
Tongue and Stock rails.

When viewed from a position facing the nose of points, the tongue and stock rails on the right are right-hand tongue and stock rails and those on the left are left-hand ones.

Crossings.

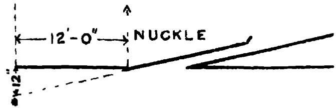
When viewed from a position facing the nose of a crossing, a right-hand crossing has the splice rail on the right-hand side and a left-hand crossing has the splice on the left-hand side as shown in diagram No. 3.

Crossings should always be laid with the full rail on the more important track (usually the straight track) so that a Turn-out to the right will require a right-hand crossing and a turn-out to the left a left-hand one.

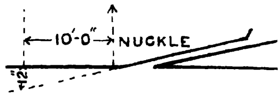


NOMENCLATURE OF SWITCHES AND CROSSINGS.

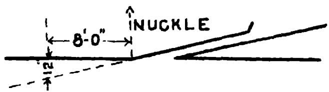
DIAGRAM No. 3.



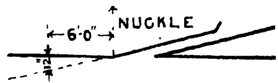
1 IN 12



1 IN 10



1 IN 8



1 IN 6

WING RAILS OF CROSSINGS.

DIAGRAM No. 4

7. WING RAILS OF CROSSINGS.

Diagram No. 4.

The point at which the wing rail is bent to form the frog of crossing is called the nuckle or elbow of the wing rail. The methods of finding out the distances from the actual nose to theoretical nose of crossing and from theoretical nose of crossing to elbow of the wing rail or from actual nose of crossing to elbow of wing rail are described below :—

(*a*) To find the distance from actual nose of crossing to its theoretical nose :—

> 'Multiply the thickness of the nose by the number of crossing.'

(*b*) To find the distance from theoretical nose of crossing to elbow of wing rail :—

> 'Multiply the number of crossing by $1\frac{3}{4}$.' ($1\frac{3}{4}$ being the flange-way clearance of the crossing rails.)

(*c*) To find the distance from actual nose of crossing to elbow of wing rail :—

> 'Multiply the number of crossing by $2\frac{1}{2}$.' ($2\frac{1}{2}$ being the sum of flange-way clearance and the thickness of the actual nose of crossing, $1\frac{3}{4}$ plus $\frac{3}{4} = 2\frac{1}{2}$.)

Example :—

		a	b	c
Number of crossing.	Thickness of nose of crossing in inches.	Thickness of nose of crossing × number of crossing = Distance from actual nose to theoretical nose of crossing in inches.	Number of crossing × Flange-way clearance $1\frac{3}{4}''$ = Distance from theoretical nose to elbow of wing rail in inches.	Number of crossing × sum of flange-way clearance plus thickness of nose $2\frac{1}{2}''$ = Distance from actual nose to elbow of wing rail in inches.
1 in 6	$\frac{3}{4}$	$4\frac{1}{2}$	$10\frac{1}{2}$	15
1 in 8	,,	6	14	20
1 in $8\frac{1}{2}$	,,	$6\frac{3}{8}$	$14\frac{7}{8}$	$21\frac{1}{4}$
1 in 9	,,	$6\frac{3}{4}$	$15\frac{3}{4}$	$22\frac{1}{2}$
1 in 10	,,	$7\frac{1}{2}$	$17\frac{1}{2}$	25
1 in 12	,,	9	21	30
	and so on			

The action of wheels passing over the crossings renders the wing rails liable to wear out more quickly than any other part of the crossing. Such worn out rails are unpleasant as they cause a regular bump on the crossing and should be renewed as soon as the top-table of the wing rail in front of the frog is worn out about $\frac{1}{4}$ inch. New wing rails of the proper spread for the different crossings should be made as follows :—

Take a rail 15 feet long and mark on it the place where you wish to have your nuckle or elbow. Put your jim-crow on this mark and bend the rail to the right or to the left as you may want. Put a small bar in the mouth of the jim-crow while bending the rail so as to have a sharp nuckle instead of a flat one. Now make a mark on the rail from the nuckle at a distance of 6, 8, 10 or 12 feet or at any distance for whatever number of crossing the wing may be wanted. Hold your height-board in line with the face of the bent portion of the rail in the direction of the dotted line and measure the spread from running edge of the rail to the face of the height board. For a 1 in 6 crossing, you should have a 1 foot spread at a distance of 6 feet from the nuckle; for a 1 in 8 crossing, the spread should be 1 foot at a distance of 8 feet from the nuckle; for a 1 in 10 crossing, at 10 feet from the nuckle and so on. The end of the wing rail should be bent so as to be $4\frac{3}{4}$ inches from the crossing rail. The bend at the end should be gradual and not abrupt. The jim-crow should be applied gradually till the rail is bent to the required spread otherwise there is every possibility of the rail breaking off. To avoid this, it is desirable to heat the rail before bending with the jim-crow. There will then be no danger of the rail breaking. Wing rails of bull headed or double headed rails of any section are very easily made in this way and replaced at any time without waiting for new ones to be supplied.

8. TO FIND OUT THE NUMBER OF DIAMOND CROSSINGS.

Diagram No. 5.

Mark the place where the distance between the gauge lines is 6 inches wide across and measure the distance from this point to centre of elbow of wing rail. Then divide this distance in inches by 6. The quotient will be the number of the diamond crossing.

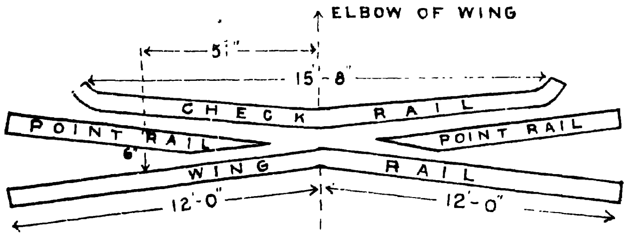
Example :—

If the distance from the point where the width of gauge lines is 6 inches wide across (see diagram No. 5) to the centre of elbow of the wing rail is 51 inches, the crossing is 1 in $8\frac{1}{2}$. If it is 48 inches, it is 1 in 8. If it is 60 inches, it is 1 in 10 and so on.

9. CURVE LEAD.

Diagram No. 6.

(*a*) AB is a cord giving us the versine of the arc at the centre point, which is the tangent point of our turn-out. The distance from tangent point to theoretical nose of crossing is therefore equal to half of the cord AB. The versine in this case is 5′-6″, which is equal to our gauge. Let us now assume that our crossing is 1 in 8 and that its radius is 704 feet.



1 IN $8\frac{1}{2}$ DIAMOND CROSSING.

DIAGRAM No. 5.

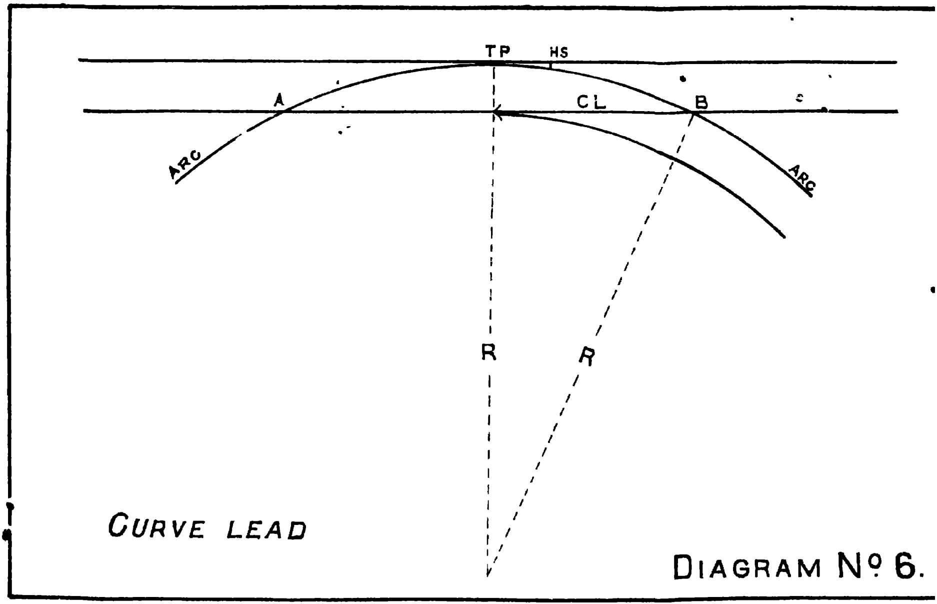
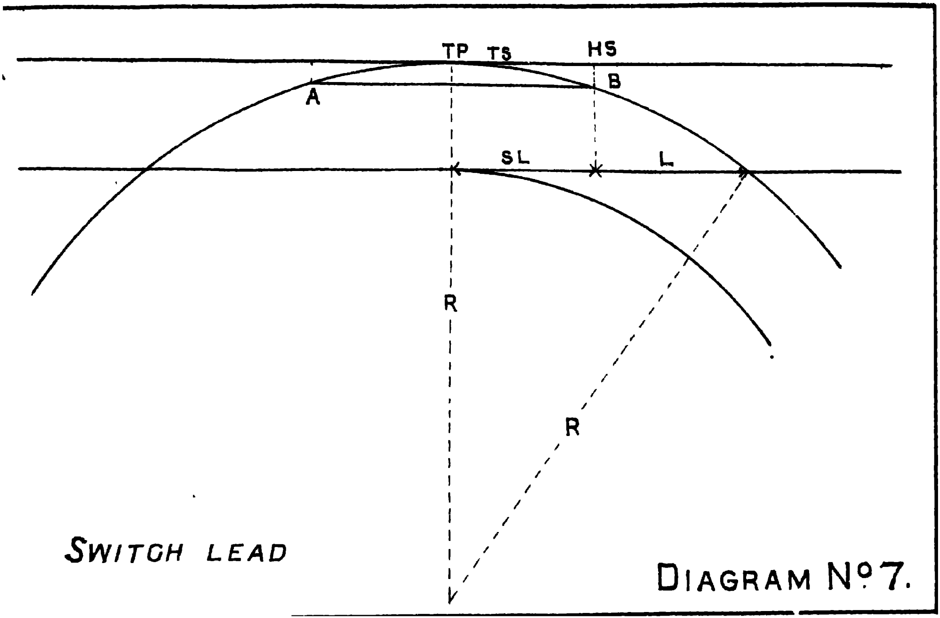


DIAGRAM No. 6.



SWITCH LEAD

DIAGRAM No. 7.

Then to find the length of this half cord, we have :—

$\sqrt{(\text{Diameter} - \text{Versine}) \times \text{Versine}} = \frac{1}{2}$ cord.

(704 feet radius × 2 = 1408 feet diameter.)

$= \sqrt{(1408 - 5\frac{1}{2}) \times 5\frac{1}{2}}$

$= \sqrt{1402\frac{1}{2} \times 5\frac{1}{2}}$ = 7713 75

$= \sqrt{7711} = 88$ nearly.

= 88 being half cord or curve lead, the distance from tangent point to theoretical nose of crossing measured along the straight.

(*b*) $\frac{C^2}{2\,R}$ = Versine = 5·5 feet.

conversely $2\,R \times \text{Versine} = C^2$

therefore $C^2 = 2 \times 704 \times 5 \cdot 5.$

$\therefore \quad C = \sqrt{2 \times 704 \times 5 \cdot 5} = 88$

$\therefore$ 88 = Half cord or curve lead.

(*c*) CL or curve lead is equal to (2 G N) where G is the gauge and N the number ~~or lead~~ of crossing,
therefore $2 \times 5\frac{1}{2} \times 8 = 88$ which is CL or curve lead.

10. SWITCH LEAD.

Diagram No. 7.

(*a*) AB is a cord giving us the versine of the arc at the centre point, which is our tangent

point of the turn-out. The versine in this case is equal to the clearance from running edge to running edge of rails at heel of switch which is $4\frac{1}{2}$ inches. Then to find out the length of half the cord AB, we have:—

$\sqrt{(\text{Diameter}-\text{Versine}) \times \text{Versine}} = \frac{1}{2}$ cord.

(704 feet radius $\times$ 2 = 1408 feet diameter.)

$= \sqrt{(1408 - \frac{3}{8}) \times \frac{3}{8}}$

$= \sqrt{1407\frac{5}{8} \times \frac{3}{8}}$ $\sqrt{527.56}$

$= \sqrt{528} = 23$ nearly. $= 22$

∴ 23 = Half cord or switch lead being the distance from tangent point to heel of switch measured along the straight.

(*b*) SL or switch lead is equal to $(2{\cdot}8 \times N)$ where N is the number of crossing.

Example :—

N is 1 in 8

therefore $2{\cdot}8 \times 8 = 22{\cdot}4$ or say 23 which is SL or switch lead.

---

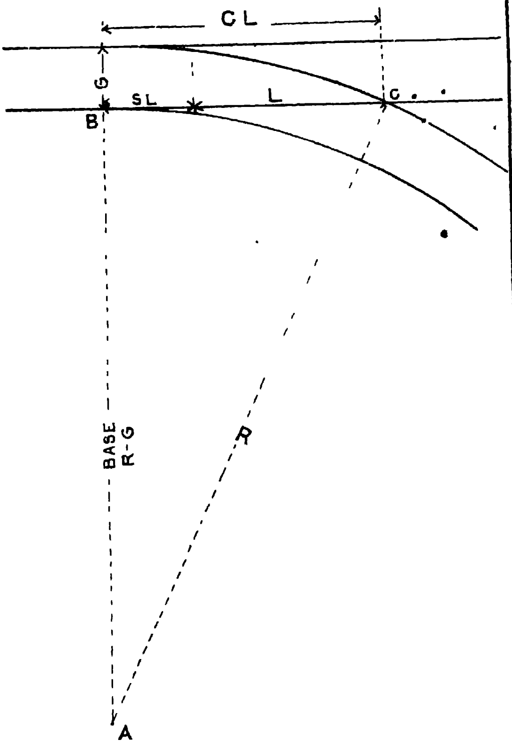
11. LEAD OF CROSSING.

It will be now understood that CL or curve lead minus SL or switch lead, would be equal to L, the lead of crossing.

CL — SL = L, the lead of crossing

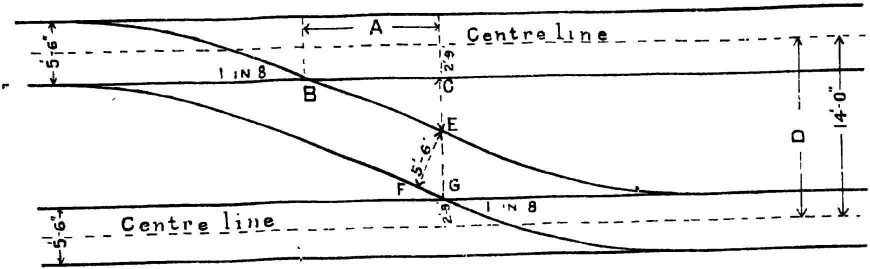
or L or lead of crossing $= (8{\cdot}2 \times N)$

$= 8{\cdot}2 \times 8 = 65{\cdot}6$.



Radius of Crossing

Diagram No 8.



DISTANCE BETWEEN CROSSINGS.

DIAGRAM No 9.

12. RADIUS OF CROSSING.

Diagram No. 8.

In diagram 8, ABC is a right-angled triangle. AB is the base and BC the offset which is equal to curve lead or 2GN. Now find out AB the base when offset BC is known :—

AB is equal to $R - G = CL \times N$ or $2GN^2$ therefore R is equal to $2GN^2$ approximately, or $2GN^2 + 1\frac{1}{2}$ G very closely,

where $G = 5'\text{-}6''$

$N = 1$ in 8

$$\therefore \quad 2 \times 5\tfrac{1}{2} \times 8^2 + 1\tfrac{1}{2} \times 5\tfrac{1}{2}$$

$$= \quad 11 \times 64 + 8\tfrac{1}{4}$$

$$= \quad 704 + 8\tfrac{1}{4}$$

$= \quad 712\frac{1}{4}$ or say 712 radius.

13. DISTANCE BETWEEN CROSSINGS.

Diagram No. 9.

Let us assume that our roads are at 14 feet centres, the gauge is 5′-6″ and the numbers of crossings are 1 in 8.

In diagram 9, BCE is a right-angled triangle of which BC is the base and CE the offset which is equal to $D - 2G$ ($14 - 11 = 3$) approximately. Find out the base.

'To find out base if perpendicular offset is known' :—

'Multiply the perpendicular offset with co-tangent a.'

3, Perp. offset × 8, co-tangent a
$= 3 \times 8 = 24$ approximately.

In the above, we have assumed that the offset CE is equal to D — 2G but this is not strictly correct. The distance EF at right angles to the cross-over line is 5′-6″. The distance EG, at right angles to the main track is obviously a little longer than EF or the gauge.

The formula (D — 2G) N is therefore only approximate as it assumes that the distance EG is only 5′-6″ when it is obviously a little longer. To find the difference between EF and EG, we shall have to further dive into Trigonometry, which is not my purpose to do. It will suffice for the purpose of a practical plate-layer to know that this difference between EF and EG is accounted for by the term $\frac{D}{4N}$. The correct formula to find out the distance between crossings TNC to TNC would therefore be $(D - 2G)N - \frac{D}{4N}$. $\rightarrow \frac{G}{2N}$ more Correct.

Therefore $(D - 2G)\,N \quad \dfrac{D}{4\,N}$

$$= \quad (14 - 2 \times 5\tfrac{1}{2}) \times 8 - \frac{14}{4 \times 8}$$

$$= \quad (14 - 11) \times 8 - \frac{14}{32}$$

$$= \quad (3) \times 8 - \frac{14}{32}$$

$$= \quad 24 - \frac{14}{32} = 23\,\frac{9}{16}$$

$=$ $23'$-$6\frac{3}{4}''$. This is the correct length of BC the base.

CHAPTER III.

Measurements of Points and Crossings.

14. LAYING POINTS AND CROSSINGS.

Prefatory remarks.

BEFORE commencing to lay points and crossings, it is advisable to take all measurements, carefully making due allowance for expansion and have all rails and closures nicely cut and drilled, care being taken to see that no burrs are left in fish bolt holes. Crossings must be laid to exact distances but a little allowance may be made in practice to save unnecessary cutting of rails, bearing it in mind that if the lead is made longer than the correct one, there will be an ugly kink near the crossing. If it is made shorter, there will be a piece of straight near the crossing which is a good thing.

Always spike the straight line first by the eye and then bring the curved rail to exact gauge at heel of switch and spike the heel chair. With crossings the rule as to spiking the straight line first, also applies *i. e.*, first spike the check chairs on the straight line, then the crossing and last of all the check chairs of the curved side. The gauge should always be tried at the nose of crossing and at each end and care should be taken to see that

all three places are exact gauge before any portion is spiked. The gauge should be kept on until all the spikes are well driven home.

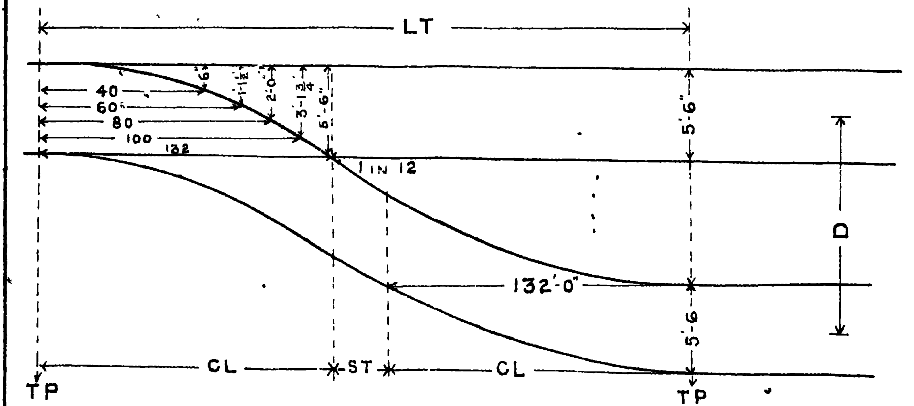
2. It has been a practice in the past to spike points and crossings from ½″ to ¾″ tight to gauge but this has since been prohibited and it is now generally laid down that points and crossings must be laid to exact gauge. Moreover the gauge between points and crossings should be uniform from one end to the other and that it must not vary.

3. The tie rods for points should be of proper length and if the points are laid to exact gauge, the throw or the clear distance between the nose of switch and the stock rail will be 4½″. The points must always be fitted with locking bolts on either side so that they could be set and locked for one road or the other as required. With points having round tie rods between the tongue rails, the main defect is that the toe of switch jumps up as soon as its heel is pressed by a passing vehicle and while a train is passing over a pair of points pressing the heel on and off, the toe of switch keeps jumping and damages the stock rail. To prevent this jumping of toe of switch, new pattern tie rods called "Williams' Stretcher bars" are now used as they effectively prevent the jumping. If they are not available, a piece of 3″ T iron 6½ feet long should be passed from underneath the stock and

tongue rails and so bolted to the tongue rails by means of brackets that it will just touch the underside of the stock and tongue rails and easily slide along with the tongue rails when the point lever is worked one side or the other. Being fixed under the stock and the tongue rails, this T bar will effectively stop the jumping of toe of switch even when its heel is pressed. Heel bolts with cast iron distance blocks and creep bars should be used to prevent the switch rails from creeping ahead and fouling points should be fixed to show where vehicles may be left without fouling the adjacent lines.

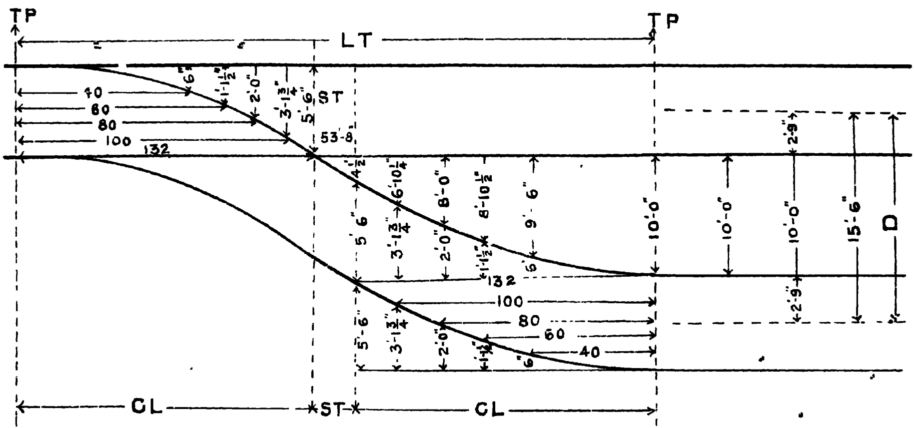
4. Check rails should be never less than 7½ feet long and the bend at the end should not be too abrupt. If check rails are short in length, they should be placed well forward to protect the nose of the crossing. The front end of the check rail should be at least 3 feet ahead of the nose of crossing, so that it may safely guide the wheel past the gap in front of the nose. The check rail should be bolted with three bolts, one in the centre and one at each end, to the running rail to prevent it from tilting in case the keys were slack, which might cause a derailment. The proper distance between the check and running rail flanges is 1¾ inches.

5. On Construction or new works, a platelayer can take his own time and do the work at



TO SET OUT A CURVE LEAD BY OFFSETS.

DIAGRAM No 10



To set out a turn-out by offsets.

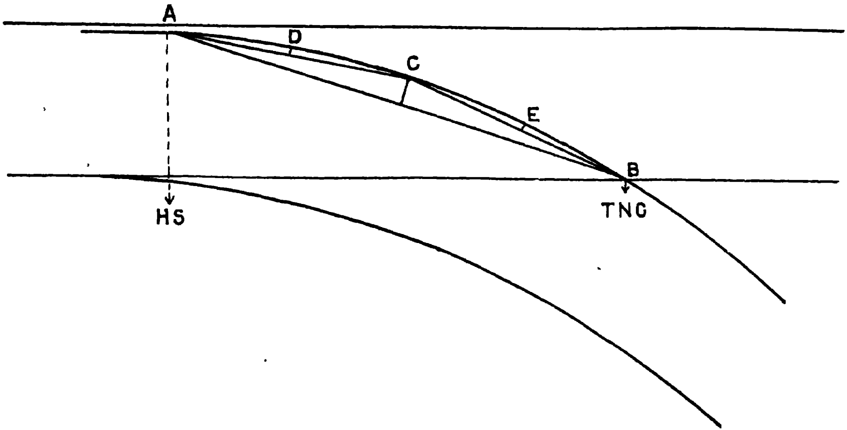
DIAGRAM No. 11

case, but such is not the case when alterations are to be made in running main lines where work is got to be done within a given time. It is always advisable in such cases to mark out the position of the alterations before attempting to break the road and have all materials ready at hand. Always ask for an hour or so more than you think you would want to finish the work as it is very likely that some unforeseen circumstances might crop up in your way and hamper the work. If however, you fail to do the work in the given time, do not get excited, but put yourself calmly to it and see it is properly done. Never remove your protection flags until every thing is finished, no matter what trains you detain, because it is comparatively very easy to explain the detention of half an hour than to explain an accident.

15. TO SET OUT CURVE LEAD OF A CROSSING AND TURN-OUT BY OFFSETS.

Diagram Nos. 10 and 11.

In diagram 10, let us assume that the turn-out is of a 1 in 12 crossing with 96 feet lead, and radius of curve 1592 feet.



TO ALIGN A CURVE OF CROSSING TO A GIVEN RADIUS.

DIAGRAM Nº 12.

We therefore have :—

offset.

$$\frac{132^2}{2R} = \frac{132 \times 132}{2 \times 1592} = \frac{17424}{3184} = 5'\text{-}6''$$

$$\frac{100^2}{2R} = \frac{100 \times 100}{2 \times 1592} = \frac{10000}{3184} = 3'\text{-}1\tfrac{3}{4}''$$

$$\frac{80^2}{2R} = \frac{80 \times 80}{2 \times 1592} = \frac{6400}{3184} = 2'\text{-}0''$$

$$\frac{60^2}{2R} = \frac{60 \times 60}{2 \times 1592} = \frac{3600}{3184} = 1'\text{-}1\tfrac{1}{2}''$$

$$\frac{40^2}{2R} = \frac{40 \times 40}{2 \times 1592} = \frac{1600}{3184} = 0'\text{-}6''$$

We have now found out the offsets for these cords. Spike down your curve line fixing it at these offsets and you will have got your curve correctly laid to the proper radius. The same method can be adopted in setting out the curve of a turn-out as explained in diagram 11. The offsets are to be measured from gauge side to gauge side of rails.

16. ANOTHER METHOD TO ALIGN OR SET OUT A CURVE BETWEEN POINTS AND CROSSINGS TO A GIVEN RADIUS.

Diagram No. 12.

The curves between points and crossings at times get out of alignment due to various reasons

and it is necessary to adjust them to their proper radius. If this is not done, they look very ugly as either kinks or straight portions are formed in the lead. A good method of re-adjusting such curves is explained in diagram 12. The formula for finding out the versine is $\frac{\frac{1}{2}\text{ cor}}{2R} =$ Versine.

In diagram 12, measure the cord AB from the heel of switch to theoretical point of crossing and mark the point C midway between A and B. The versine or offset at C will be equal to $\frac{\frac{1}{2}\text{ cord}^2}{2R}$ which in this case, we shall assume to be as under :—

Cord AB is 68 feet.

Radius of crossing is 712 feet.

Since AB is 68 feet, AC which is half of AB, is equal to 34 feet.

$$\text{therefore } \frac{\frac{1}{2}\text{ cord}^2}{2R} = \frac{AC^2}{2R} = \frac{34^2}{2 \times 712} = \frac{1156}{1424} =$$

$9\frac{3}{4}$ inches offset or versine at the point C.

We have now found out the versine at C. Hold a string tightly stretched between A and B an measure the versine at C. Slew the curve lir until you get the correct offset at C which in th case is $9\frac{3}{4}$ inches. The same method can again followed to determine the offsets at D and

Measure the cords A C and C B and mark the midway points D and E. The offset or versine at D will be equal to $\frac{\frac{1}{2}\ \text{cord}^2}{2R}$. Since A C is 34 feet, A D which is half of A C, is equal to 17 feet.

Therefore $\frac{\frac{1}{2}\ \text{Cord}^2}{2\ R} =$

$$\frac{AD^2}{2R} = \frac{17^2}{2 \times 712} = \frac{289}{1424} = 2\tfrac{7}{16}''$$ offset or versine at the point D.

Similarly the offset at E will be=

$$\frac{\frac{1}{2}\ \text{Cord}^2}{R} = \frac{C\ E^2}{2\ R} = \frac{17^2}{2 \times 712} = \frac{289}{1424} = 2\tfrac{7}{16}''$$ offset or versine at the point E.

It will be seen that the offsets at D and E will be exactly ¼th of that at C. Having now determined the offsets at D and E, slew the curve at hese points until you get the correct offsets taking ıre not to move or shift the point C already fixed. ɔu will then find that your curve between the ıl of switch and the theoretical nose of crossing correct to the given radius which in this case is ımed to be 712 feet.

17. Turn-outs with straight between reverse curves.

Diagram No. 13.

In diagrams 6 to 9, we have learnt to find out the curve lead, switch lead, lead and radius of crossing and also distances between crossings. However the formulæ are repeated here :—

To find (S L) the switch lead :—$(2{\cdot}8 \times N)$

To find (C L) the curve lead :—$(2\ G\ N)$

or :—$\sqrt{(\text{Dia.}-V) \times V}$

$= \frac{1}{2}$ cord $=$ CL.

To find (L) the lead ....:—$C\ L - S\ L =$ Lead

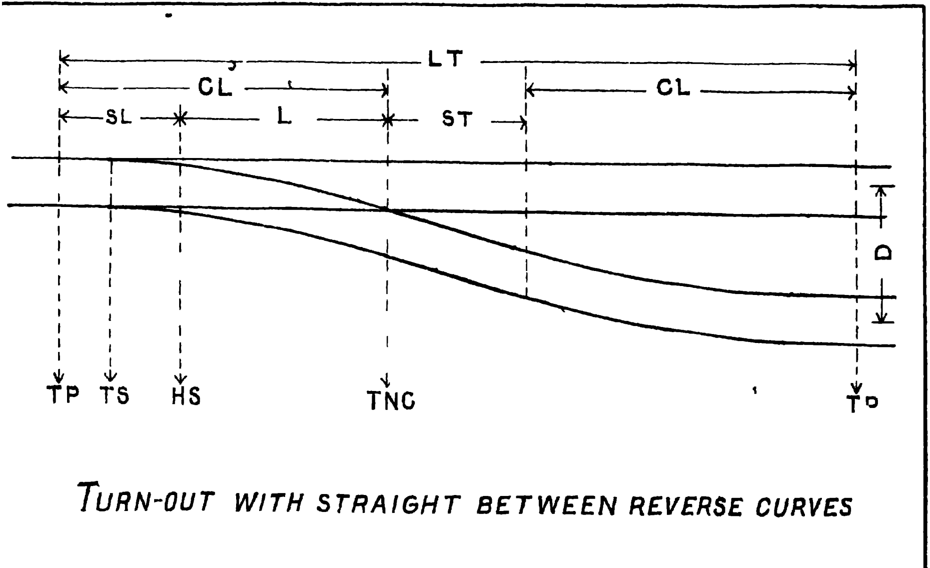
or :— $(8{\cdot}2 \times N) =$ Lead.

To find (S T) the length of straight track between the reverse curves. } $(D - 2G)\ N - \dfrac{D}{4N}$

To find (L T) the length of the turn-out T. P. to T. P. } $(D + 2G)\ N$

To find (R) the radius of crossing. $(2\ G N^2 + 1\frac{1}{2} G)$

To find (N) the number of crossing. } $\sqrt{\dfrac{R - 1\frac{1}{2}\ G}{2\ G}}$



Turn-out with straight between reverse curves

Solution :—

Let us assume that

$$G \text{ is } = 5\tfrac{1}{2} \text{ feet.}$$
$$N \text{ is } = 1 \quad \text{in } 12.$$
$$D \text{ is } = 14 \text{ feet.}$$

Then to find :—

$(SL) = (2 \cdot 8 \times N) = 2 \cdot 8 \times 12 = 33 \cdot 6$ feet.

$(CL) = (2\ G\ N) = 2 \times 5\tfrac{1}{2} \times 12 = 132$ feet.

or $\sqrt{(\text{Dia.} - V) \times V} = \tfrac{1}{2}$ cord $= C\,L.$

($1592\tfrac{1}{4}$ feet radius $\times\ 2 = 3184\tfrac{1}{2}$ feet diameter.)

$$= \sqrt{(3184\tfrac{1}{2} - 5\tfrac{1}{2}) \times 5\tfrac{1}{2}}$$
$$= \sqrt{3179 \times 5\tfrac{1}{2}}$$
$$= \sqrt{17484}$$
$$= \quad 132 \text{ feet.}$$

$(L) = CL - SL = L$

$= 132 - 33 \cdot 6 = 98 \cdot 4$ feet.

or $(8 \cdot 2 \times N) = 8 \cdot 2 \times 12 = 98 \cdot 4$ feet.

$$(ST) = (D - 2\ G)\ N - \frac{D}{4N}$$

$$= (14 - 11)\ 12 - \frac{}{48}$$

$$= 3 \times 12 - 0 \cdot 291$$

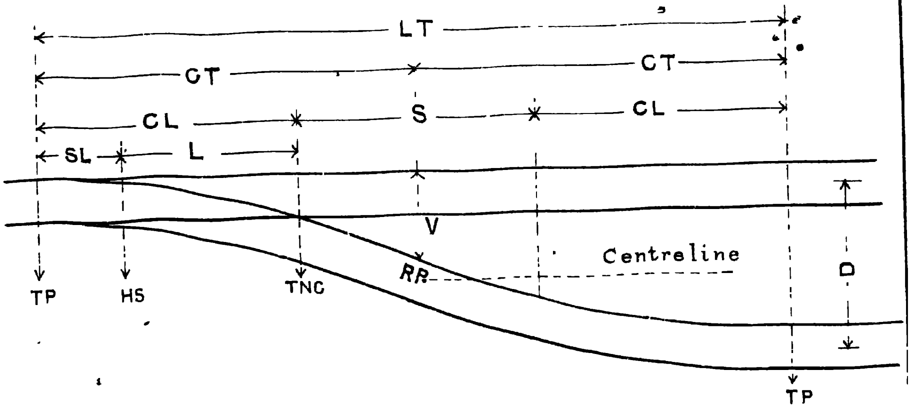
$$= 35 \cdot 709 = 35'\text{-}8\tfrac{1}{2}''$$

$$
\begin{aligned}
(LT) &= (D + 2\ G)\ N \\
&= (14 + 2 \times 5\tfrac{1}{2})\ 12 \\
&= 25 \times 12 \\
&= 300 \text{ feet.} \\
(R) &= (2\ G\ N^2 + 1\tfrac{1}{2}\ G) \\
&= (2 \times 5\tfrac{1}{2} \times 12 \times 12 + 1\tfrac{1}{2} \times 5\tfrac{1}{2} \\
&= 1584 + 8\tfrac{1}{4} \\
&= 1592\tfrac{1}{4} \text{ feet.} \\
(N) &= \sqrt{\frac{R - 1\tfrac{1}{2}\ G}{2\ G}} \\
&= \sqrt{\frac{1592\tfrac{1}{4} - 1\tfrac{1}{2} \times 5\tfrac{1}{2}}{2 \times 5\tfrac{1}{2}}} \\
&= \sqrt{\frac{1592\tfrac{1}{4} - 8\tfrac{1}{4}}{11}} \\
&= \sqrt{\frac{1584}{11}} \\
&= \sqrt{144} \\
&= 12 \text{ number.}
\end{aligned}
$$

18. TURN-OUTS WITH REVERSE CURVES.

Diagram No. 14.

The values of SL, CL, L, N and R remain the same as before as explained in diagram 13 under *turn-outs with straight between reverse curves.*



Turn-out with Reverse Curves.

DIAGRAM No. 14.

The only changes in this case are the distances CT and LT.

To find (CT) the distance from T. P. to the reversing point of the turn-out. } $\frac{1}{2}\sqrt{D(4R-2G-D)}$

or it could also be found out by inverting formula $\frac{C^2}{2R}$ = versine where versine is known.

To find (L T) the distance from T. P. to T. P. the full length of turn-out. } $\sqrt{D(4R-2G-D)}$

Solution:—

(*a*)
$$\begin{aligned} CT &= \tfrac{1}{2}\sqrt{D(4R-2G-D)} \\ &= \tfrac{1}{2}\sqrt{14(4\times 1592\tfrac{1}{4}-2\times 5\tfrac{1}{2}-14)} \\ &= \tfrac{1}{2}\sqrt{14(6369-11-14)} \\ &= \tfrac{1}{2}\sqrt{14(6344)} \\ &= \tfrac{1}{2}\sqrt{(88816)} \simeq \tfrac{1}{2}\times 298\cdot 02 \\ &= \tfrac{1}{2}\times 298 \\ &= 149 \text{ feet} \end{aligned}$$

(*b*) C T.

The reversing point of the turn-out lies exactly in the centre of the distance D between the two

tracks *i. e.*, it is $\frac{1}{2}$ D. When offset V which is equal to half D is known, we can find out the length CT by inverting formula $\frac{C^2}{2R}$ = versine.

$$\therefore \quad \frac{C^2}{2R} = \text{V which in this case is } \tfrac{1}{2}\text{D} = 7 \text{ feet}$$

$$\therefore \quad C^2 = 2R \times V = 2 \times 1592\tfrac{1}{4} \times 7$$

$$\therefore \quad C = \sqrt{2 \times 1592\tfrac{1}{4} \times 7} = 149$$

$$\therefore \quad 149 = \text{CT or half the length of the turn-out T. P. to R. P.}$$

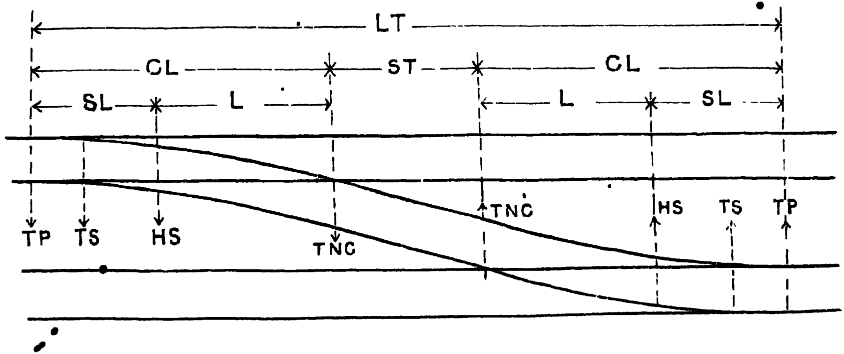
$$\begin{aligned}
(\text{L T}) &= \sqrt{\text{D}\,(4\text{R} - 2\text{G} - \text{D})} \\
&= \sqrt{14\,(4 \times 1592\tfrac{1}{4} - 2 \times 5\tfrac{1}{2} - 14)} \\
&= \sqrt{14\,(6369 - 11 - 14)} \\
&= \sqrt{14\,(6344)} \\
&= \sqrt{(88816)} \\
&= 298 = \text{length of turn-out T. P. to T. P.}
\end{aligned}$$

Comparing LT in diagram 13 with LT in diagram 14, it will be seen that the former is 300 while the latter is 298 or 2 feet short due to reverse curve.

19. Cross-over roads.

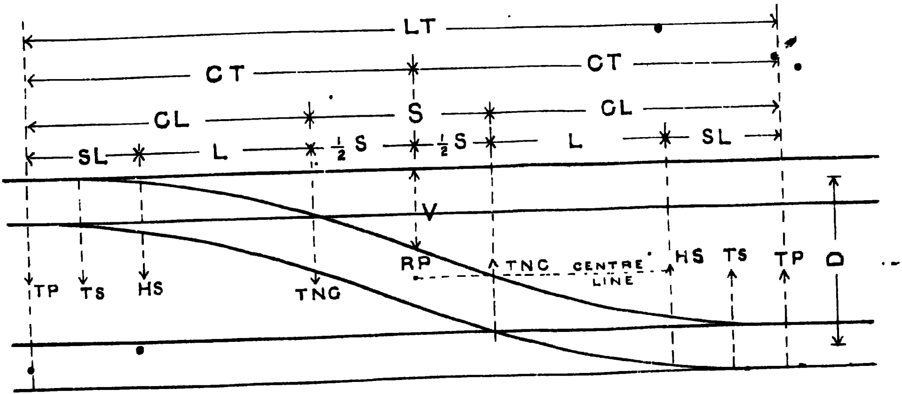
Diagram Nos. 15 and 16.

Cross-over roads are of two kinds, one with straight between reverse curves and the other with



Cross-over road with straight between reverse curves.

Diagram No. 15.



Cross-over road with reverse curves.

Diagram No. 16.

reverse curves exactly the same as turn-outs. Diagram 15 shows a cross-over with straight between reverse curves. The values of CL, SL, L, N, R, ST and LT are exactly the same as shown in diagram 13 and worked out in solution under turn-outs with straight between reverse curves.

With cross-over roads with reverse curves the values of CL, SL, L, N and R are the same as for cross-over roads with straight between reverse curves. The only difference is in the distance between the two crossings and the distance LT. Distances CT and LT of these cross-over roads are the same as shown in diagram 14 under turn-outs with reverse curves.

$$CT = \tfrac{1}{2}\sqrt{D\,(4R - 2G - D)} = 149 \text{ feet.}$$

$$\text{or } \frac{C^2}{2R} = V \text{ where V is known being} = \tfrac{1}{2} D = 7 \text{ feet.}$$

$$\therefore\ C^2 = 2 \times 1592\tfrac{1}{4} \times 7$$

$$\therefore\ C = \sqrt{2 \times 1592\tfrac{1}{4} \times 7} = 149 \text{ feet.}$$

$$LT = \sqrt{D\,(4R - 2G - D)} = 298 \text{ feet.}$$

Distance between crossings in cross-over roads with reverse curves. $= \sqrt{D\,(4R - 2G - D)} - 4GN.$

$$\text{or } (CT - CL) \times 2.$$

Solution :—

(*a*) $= \sqrt{14\,(4 \times 1592\tfrac{1}{4} - 2 \times 5\tfrac{1}{2} - 14)}$
$- 4 \times 5\tfrac{1}{2} \times 12.$

$= \sqrt{14\,(6369 - 11 - 14)} - 264$

$= \sqrt{14\,(6344)} - 264.$

$= \sqrt{88816} - 264$

$= 298 - 264$

$= 34$ feet. Distance between the two crossings TNC to TNC.

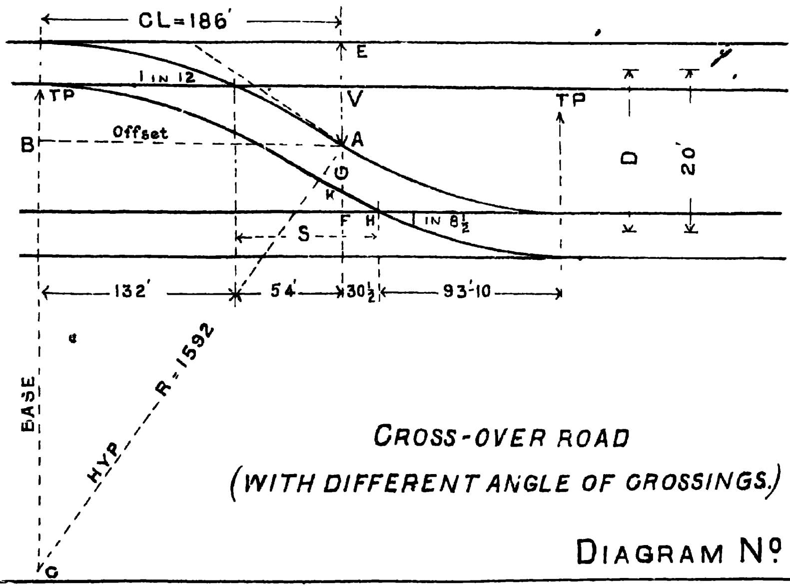
(*b*) CT — CL $= \tfrac{1}{2}$S. CT is the distance from TP to RP, the reversing point of the cross-over road which we have found out to be 149 feet. Deduct from this the curve lead and we will get the length of $\tfrac{1}{2}$S. (149—132=17). S is therefore equal to 34 feet.

Comparing S the distance between the TNC of the two crossings of a cross-over road with reverse curves with ST, the same distance of cross-over roads with straight between reverse curves, it will be noticed that S is shorter than ST which is due to reverse curves.

20. Cross-over roads with different angle of crossings.

Diagram Nos. 17 and 18.

Usually the two crossings in a cross-over road are of the same angle but sometimes it so happens



CROSS-OVER ROAD

(WITH DIFFERENT ANGLE OF CROSSINGS.)

DIAGRAM No. 17.

that they are not and one crossing has a bigger angle than the other. In such cases the distances between the two crossings have to be separately worked out as shown in diagrams 17 and 18. The common practice of taking the mean of the two angles is a fudge and never gives good results.

In diagram 17, the two crossings in the cross-over road are 1 in 12 and 1 in $8\frac{1}{2}$. In this case the curve of the bigger crossing has to be continued until it meets the straight intermediate portion from the smaller crossing. In diagram 17, ABC is a right angled triangle of which BC is the base, AB the offset and AC the hypotenuse which is equal to R, the radius of our crossing. The hypotenuse (1592) being known, we have to find out AB the offset which is equal to CL.

To find out the offset when hypotenuse is known :—

'Multiply hypotenuse with sine *a* hypotenuse'.

CL = sine of hypotenuse of the smaller crossing 1 in $8\frac{1}{2} \times$ Hyp.

$$\left(\text{sine of 1 in } 8\tfrac{1}{2} \text{ crossing is } \frac{1}{8{\cdot}55}\right)$$

$$\therefore \text{CL} = \frac{1}{8{\cdot}55} \times \frac{1592}{1} = {\cdot}186 = \text{AB the}$$

offset.

Now that we have found out AB, the length up to which the curve of the bigger crossing continues, find out its versine at this point.

$$\text{Versine} = \frac{C^2}{2R}$$

therefore versine AE $= \dfrac{C^2}{2R}$ where C is 186 and R is 1592.

$$\therefore \quad \text{Versine AE} = \frac{186 \times 186}{2 \times 1592} = 10'\text{-}11''.$$

In triangle KFH, KF the offset is equal to D — AE + G where D = 20, AE = 10′-11″ and G = 5′-6″.

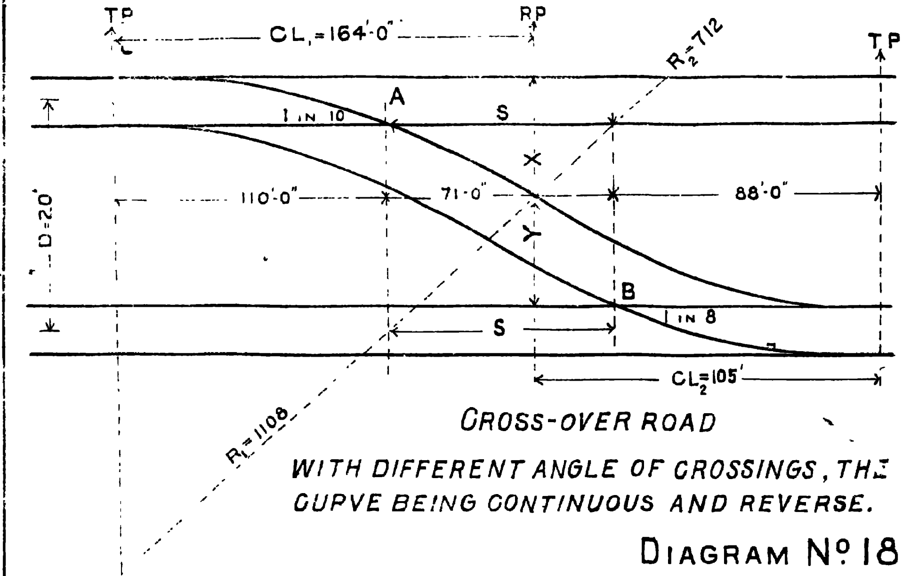
$$\therefore \text{ Offset KF} = 20 - (10'\text{-}11'' + 5'\text{-}6'') = 3'\text{-}7''.$$

Now in triangle KFH with an angle of 1 in $8\frac{1}{2}$, offset KF is known, find out FH the base.

$$\therefore \quad \text{FH} = 8\tfrac{1}{2} \times 3'\text{-}7'' = 30'\text{-}6''.$$

Now the distance between the two crossings can easily be found out as follows :—

S = 186 — 132 + 30′-6″ = 84′-6″, which consists of 54 feet curved portion and 30′-6″ straight. This is the distance between the two crossings 1 in 12 and 1 in $8\frac{1}{2}$ (132 being the curve lead of the 1 in 12 crossing.) If as is commonly taken *i. e.*, the mean of the two crossings, we would have got 91′-9″ which is out by a long way.



CROSS-OVER ROAD

WITH DIFFERENT ANGLE OF CROSSINGS, THE CURVE BEING CONTINUOUS AND REVERSE.

DIAGRAM No. 18.

21. Cross-over roads with different angle of crossings the curve being continuous and reverse.

Diagram No. 18.

In diagram No. 18, crossing A is 1 in 10 and crossing B is 1 in 8 and their radii R1 = 1108 and R2 = 712 feet and D = 20 feet or X + Y.

To find Y. $Y = \frac{R_2 \times D}{R_1 + R_2} = \frac{712 \times 20}{1108 + 712} = 7{\cdot}8$ feet.

$\therefore \quad X = D - Y = 20 - 7{\cdot}8 = 12{\cdot}2$ feet.

12·2 or X is the versine of the curve of 1 in 10 crossing and 7·8 or Y is the versine of the curve of 1 in 8 crossing, at the reversing point.

Now that we know the versines of the two curves, find out CL_1 and CL_2 by the formula $\frac{C^2}{2R}$ =versine.

(*a*) $\frac{C^2}{2R}$ = Versine = X = 12·2 which is known.

conversely 2R × Versine = C^2

$\therefore \quad C^2 = 2 \times 1108 \times 12{\cdot}2$

$\therefore \quad C = \sqrt{2 \times 1108 \times 12{\cdot}2} = 164$

$\therefore \quad 164 = CL_1$, bigger crossing.

Similarly

(*b*) $\frac{C^2}{2R}$ = Versine = Y = 7·8 which is known.

Conversely 2R × Versine = C^2

$\therefore \quad C^2 = 2 \times 712 \times 7{\cdot}8$

$\therefore \quad C = \sqrt{2 \times 712 \times 7{\cdot}8} = 105$

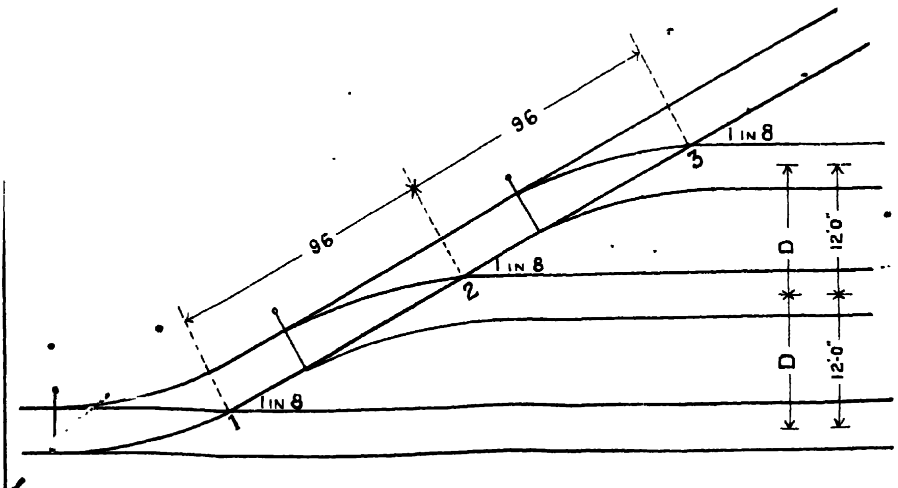
$\therefore \quad 105 = CL_2$, smaller crossing.

S = (164 + 105 − 198) = 71 feet which is the distance between the two crossings 1 in 10 and 1 in 8 (198 being the sum of the curve leads of the two crossings, 110+88=198).

22. Ladder tracks.

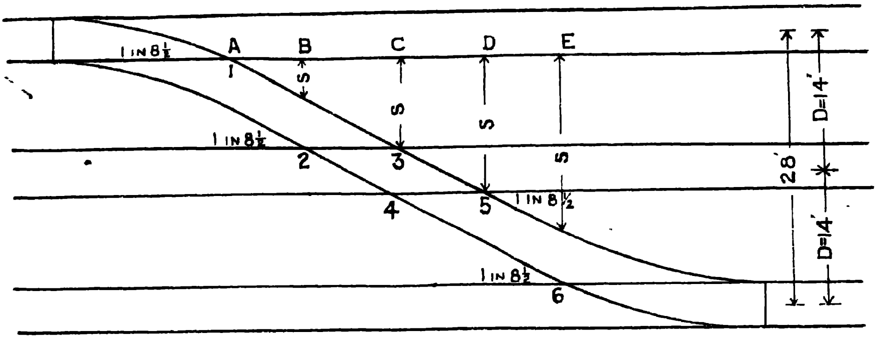
Diagram No. 19.

A gathering line or ladder track as it is called is a straight track connecting up a series of parallel sidings in a station yard. The method of arranging shunting sidings and the distances of the parallel tracks centre to centre depend upon the ground available and the requirements of the Traffic. The sidings may be any required distance apart. Sharp curves and heavy gradients should be avoided as they are expensive, more power being required to move the vehicles. The point boxes should be arranged on the opposite side of the crossings as shown in the diagram. All crossings in a ladder



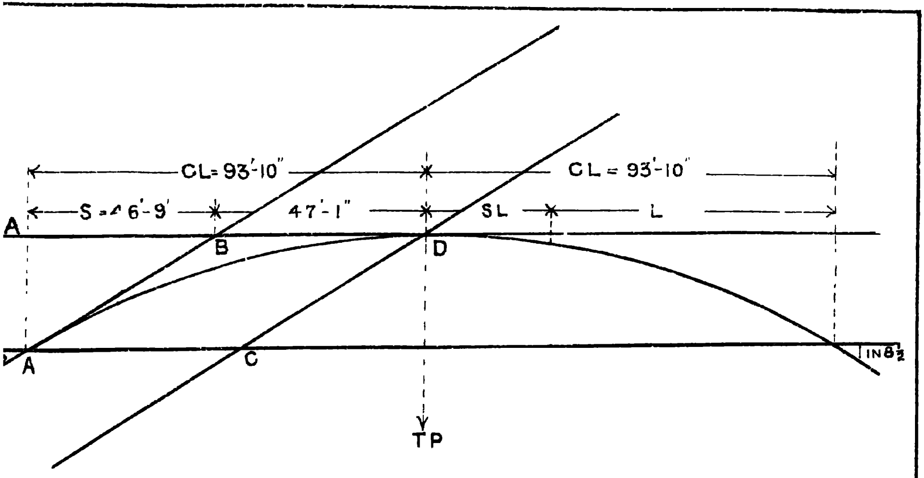
LADDER TRACK.

DIAGRAM Nº 19.



THROUGH CROSS-OVER ROAD WITH 1 IN 8½ DIAMONDS.

DIAGRAM Nº 20.



DISTANCES OF DIAMOND CROSSINGS.

DIAGRAM No. 21.

track should be of the same angle, including the crossing connecting with the main track. The distance between any two crossings leading from the ladder measured in the direction of the branches shooting from it, is equal to the distance between the centres of the parallel tracks multiplied by the crossing number.

Example :—

Let G be 5′-6″

D be 12 feet

N be 1 in 8.

Then crossings 1 to 2, 2 to 3, etc., would be = $12 \times 8 = 96$ feet measured in the direction of the ladder.

23. Through cross-over road (diamond crossings.)

Diagram Nos. 20 and 21.

When two roads cross each other, we have a "diamond crossing." According to the instructions laid down, no diamond crossing flatter than 1 in $8\frac{1}{2}$ is permissible nor should a diamond be laid in a curved track, if it can be avoided. If it is impossible to lay the diamond anywhere but in curved track, then the check rails must be lengthened in the direction of approaching vehicles so that while one pair of wheels is passing across

the gaps, the next pair behind is covered by a check rail. When a diamond crossing is laid in a curved track, the speed of trains should be reduced to about 10 miles an hour for safety. The Standard Dimensions allow of an inclination of 1 in 10 as the maximum, the extra length makes much better slip points.

Diagram 20 shows a 1 in $8\frac{1}{2}$ diamond crossing in position. The method of fixing the positions of the various crossings is explained below :—

(*a*) In diagram 20, to find the distances between the crossings 1 to 6, we have simply to find out the spread of the crossing, which when multiplied by the crossing number $-\frac{D}{4N}$ will give us the required distances.

In the diagram,

$$AB = (D-2G)N - \frac{D}{4N} = (14'-11') \times 8\tfrac{1}{2}' - \tfrac{14}{34}' = 25'\text{-}1''$$

$$AC = (D-G)N - \frac{D}{4N} = (14'-5\tfrac{1}{2}) \times 8\tfrac{1}{2} - \tfrac{14}{34}' = 71'\text{-}10''$$

$$AD = (D)N - \frac{D}{4N} = 14' \times 8\tfrac{1}{2}' - \tfrac{14}{34}' = 118'\text{-}7''$$

$$AE = (2D-2G)N - \frac{2D}{4N} = (28'-11') \times 8\tfrac{1}{2}' - \tfrac{28}{34} = 143'\text{-}8''$$

It will also be seen that :—

AC—AB (71′-10″ — 25′-1″) = BC = 46′-9″
AD—AC (118′-7″ — 71′-10″) = CD = 46′-9″
AD—AB (118′-7″ — 25′-1″) = BD = 93′-6″
AE—AD (143′-8″ — 118′-7″) = DE = 25′-1″

The inclination number of the crossing being the same at the place where it has a 1 foot spread in 8½ feet as also a 3 feet spread in 25½ feet or a 14 feet spread in 119 feet, it being a simple ratio.

The gauge of track in the diamond crossings should be ⅛th inch tight.

(*b*) In diagram 20, the position of crossing No. 1 is to be fixed as required according to your plan. When this is done, we can easily find the positions of crossing Nos. 2 and 6 as in ordinary cross-over roads by the formula $(D - 2G)N - \frac{D}{4N}$. When you have found out the positions of crossing Nos. 2 and 6, mark them on the rails and stretch a cord between these two marks. The point where the cord will cut or intersect the outer rail of the centre road, will be the position of diamond crossing No. 4. Then put your gauge at this point square to the cross-over road and mark the inner rail. This will be the position of the other diamond crossing No. 3. The position of crossing No. 5, is then to be fixed at the same distance from the diamond crossings 3 and 4, as is crossing No. 2 from them.

It should be remembered that the diamond crossings are square *i. e.*, at right angles to the cross-over and not to the main track. The gauge should therefore be held square to the cross-over road. If held square to the main track, it will cause a difference of a few inches.

(*c*) Diagram No. 21.

In diagram 21 is shown another method of fixing the distances of diamond crossings. The distance S from crossing A to B is equal to $G \times N = 5\frac{1}{2}' \times 8\frac{1}{2}' = 46'\text{-}9''$. The distance from crossing A to D is equal to the curve lead of the crossing. The curve lead of a 1 in $8\frac{1}{2}$ crossing is :—

$$\sqrt{(\text{Dia.} - V) \times V} = \tfrac{1}{2} \text{ cord} = \text{Curve lead.}$$

$$= \sqrt{(1606 - 5\tfrac{1}{2}) \times 5\tfrac{1}{2}} = 93{\cdot}82 = 93'\text{-}10''.$$

The distance from crossing A to D is therefore $93'\text{-}10''$. It will now be seen that the distance from B to D is $= 93'\text{-}10'' - 46'\text{-}9'' = 47'\text{-}1''$ as shown below :—

$AB = G \times N = 5\frac{1}{2}' \times 8\frac{1}{2}' = 46'\text{-}9''$

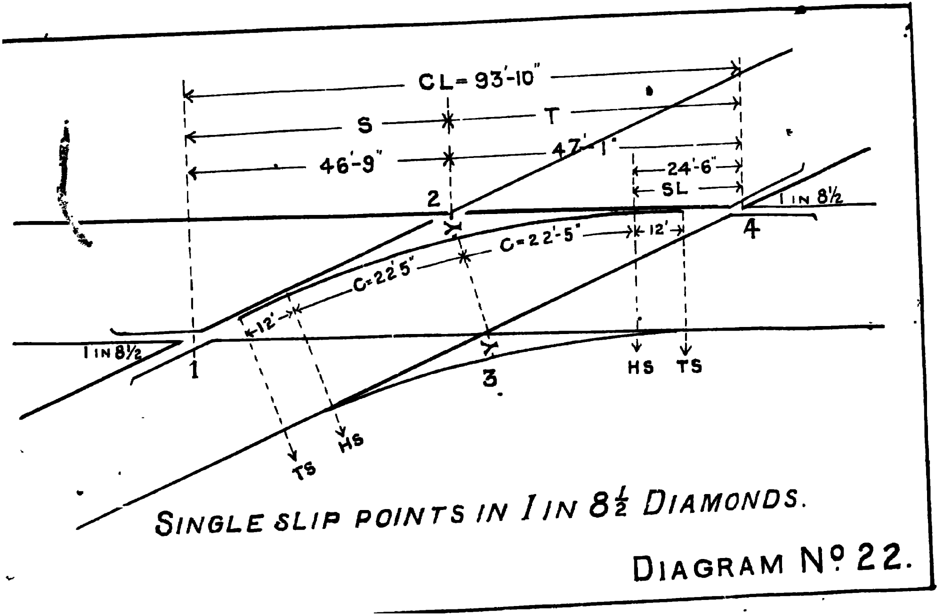
AD = Curve lead of the crossing $= 93'\text{-}10''$

$AD - AB\ (93'\text{-}10'' - 46'\text{-}9'') = BD = 47'\text{-}1''$.

24. Single or double slips in 1 in $8\frac{1}{2}$ diamonds.

Diagram No. 22.

The distance 'S' from crossing 1 to 2 is equal to $G \times N = 5\frac{1}{2} \times 8\frac{1}{2} = 46'\text{-}9''$ as in diamond cross-



SINGLE SLIP POINTS IN 1 IN 8½ DIAMONDS.

DIAGRAM No. 22.

ings. Both the diamonds being of the same angle and opposite each other, the centre of the diamonds will be exactly opposite the centre of the slip points.

The distance T is a little longer than S.

$T = G \times$ Hyp. of the crossing.

Hypotenuse of a 1 in $8\frac{1}{2}$ crossing is $= \sqrt{\text{Base}^2 + \text{Perp.}^2}$

$= \sqrt{8 \cdot 5^2 + 1^2} = \sqrt{8 \cdot 5 \times 8 \cdot 5 + 1 \times 1}$

$= 8 \cdot 558 =$ hypotenuse.

$\therefore \quad T = 5 \cdot 5 \times 8 \cdot 558 = 47 \cdot 069 = 47'\text{-}0\frac{3}{4}''$

or $T = CL - S$.

CL or curve lead of a 1 in $8\frac{1}{2}$ crossing is $= 93'\text{-}10''$.

$S = G \times N = 5\frac{1}{2} \times 8\frac{1}{2} = 46'\text{-}9''$.

$T = 93'\text{-}10'' - 46'\text{-}9'' = 47'\text{-}1''$.

This is the same as explained more clearly in diagram No. 21 under distances of diamond crossings.

$SL =$ Switch lead $= \sqrt{(\text{Dia.} - V) \times V} = \frac{1}{2}$ cord.

V is the clearance at heel of switch and is equal to $4\frac{1}{2}$ inches and Radius is 803.

$- 4\frac{1}{2}'') \times 4\frac{1}{2}'' = 24'\text{-}6''$.

$\therefore \quad 24'\text{-}6'' =$ SL or switch lead.

C the distance from centre of elbow of diamond crossing to heel of slip points is equal to $N \times 2 \cdot 64$.

$\therefore \quad C = 8 \cdot 5 \times 2 \cdot 64 = 22 \cdot 44 = 22'\text{-}5''$.

The total distance between the heels of switches on either side of the diamonds is therefore

22′-5″ + 22′-5″ = 44′-10″; and SL the switch lead is 24′-6″.

$$Y = \frac{T^2}{2R} \text{ (approx.)}$$

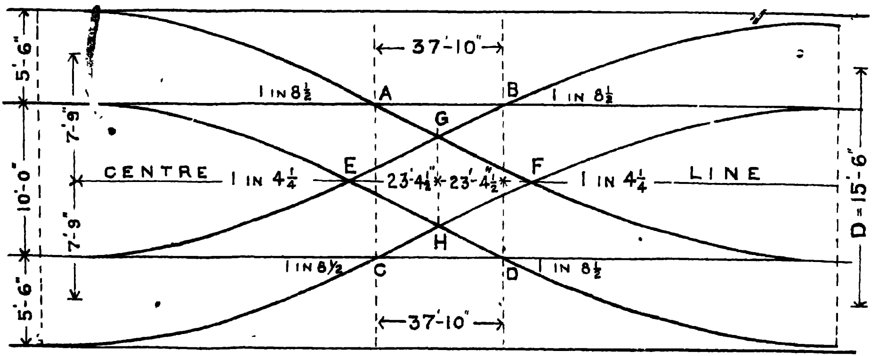
$$\therefore \quad \frac{47\tfrac{1}{12} \times 47\tfrac{1}{12}}{2 \times 803} = \frac{2216}{1606} = 1'\text{-}4\tfrac{1}{2}''.$$

The diagram shows single slip points. If the connection between the two lines were similarly made on the other side, it will make double slip points.

25. Scissors cross-over.

Diagram No. 23.

A cross-over crossing another cross-over is called a Scissors cross-over. It consists of two cross-overs running in opposite directions and is very useful where much shunting has to be done in a limited space. In a Scissors cross-over, the spread of the crossings forming the diamond is half that of the main crossings. In diagram 23, you will see that crossings A and C are on one straight line exactly opposite each other; similarly crossings B and D are on one straight line and opposite each other. Crossings G and H are exactly in the centre of crossings AB or CD. Crossings E and F lie on a straight line which is exactly in the centre of the two tracks. Crossings ABCD are 1 in 8½ and EFGH are 1 in 4¼ and the roads are 13′-6″ centres.



SCISSORS CROSS-OVER.

DIAGRAM No. 23.

The distances from heels of switches to theoretical noses of crossings ABCD measured from their respective ends are the same for all 4 crossings, since they are all of one angle. The toes of switches or heels of switches of the two points at either end are also on one straight line and exactly opposite each other.

The position of crossings A and C is fixed according to your plan. The distances of the other crossings can then be found out as follows :—

The distances between crossings A and D and C and B are found out by the usual formula $(D - 2\ G)\ N - \frac{D}{4N}$ as in ordinary cross-over roads. Distances between crossings E and G and G and F are found out by the formula $G \times N$ used for diamond crossings.

Solution :—

Where G is = 5′-6″
D is = 15′-6″
Crossings ABCD are 1 in $8\frac{1}{2}$ and
crossings EFGH are 1 in $4\frac{1}{4}$.

Distances between crossings A and D and C and B are therefore $= (D - 2G)\ N - \frac{D}{4N}$

$$= (15\tfrac{1}{2} - 2 \times 5\tfrac{1}{2}) \times 8\tfrac{1}{2} - \frac{15\frac{1}{2}}{4 \times 8\frac{1}{2}}$$

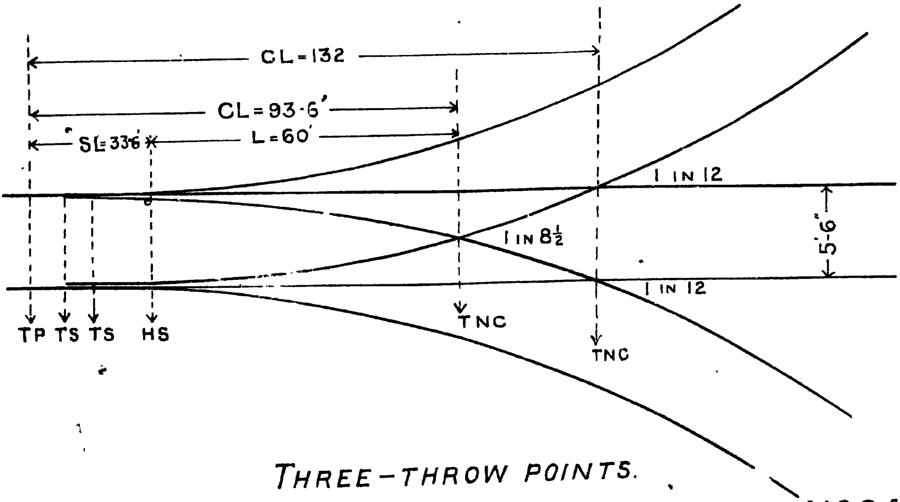
$= (15\frac{1}{2} - 11) \times 8\frac{1}{2} - \frac{31}{68}$
$= 4\frac{1}{2} \times 8\frac{1}{2} - \frac{31}{68}$
$= 38\frac{1}{4} - \frac{31}{68}$
$= 38'\text{-}3'' - 0'\text{-}5'' = 37'\text{-}10''$

Distances between crossings E and G and G and F are equal to G × N where N is $4\frac{1}{4}$,
$= 5\frac{1}{2} \times 4\frac{1}{4} = 23'\text{-}4\frac{1}{2}''$.
Distance E to F is therefore twice $23'\text{-}4\frac{1}{2}'' = 46'\text{-}9''$.

If the crossings ABCD were 1 in 12, crossings EFGH would be 1 in 6 and their distances with the roads at 15′-6″ centres would be :—

Crossings	A	to D	= 53′-8″
and	C	to B	
do.	E	to G	= 33′-0″
do.	G	to F	= 33′-0″
do.	E	to F	= 66′-0″

When any diamond crossings or scissors cross-overs are to be laid in, it is advisable to lay the whole connection outside on a level piece of ground and then slew the whole thing into its proper place. If however, there is no room to lay the whole connection at site due to a bank or want of space, lay the connection on a platform or any other level piece of ground wherever available, mark with paint the crossings, closures, sleepers, etc. in such a way as will enable you to assemble it again at site without difficulty.



THREE-THROW POINTS.

DIAGRAM No. 24.

26. Three-Throw Points.

Diagram No. 24.

When a line divides into three, two sets of points are laid in, forming what are called "Three-throw Points." Three-throw points are neither very safe nor economical and are fast becoming obsolete. If there is no room for two ordinary turn-outs, use two pairs of ordinary switches placing the stock rail of one a short distance behind the heel of the other. This will not save a crossing but it is more safer than the three-throws. The three-throws can be laid to gauge by kinking the stock rails on both sides opposite the nose of each switch rail. The curve lead, switch lead and the lead of crossing always remain the same whether the two lines diverge in opposite or in the same direction. The radii of the curves are fixed by the number of the main crossings when the lines diverge in opposite directions but when both lines diverge in the same direction, the radius of the flattest curve is fixed by the number of the main crossing and the radius of the inner or sharper curve is fixed by the number of the centre crossing.

I. To find the number of the centre or sharpest crossing in a set of three-throws :—

(*a*) 'Multiply the number of the main crossing by 0·7. The product will be the number of the centre crossing.'

Example :— If the number of the main crossing is 1 in 12, we have $12 \times 0 \cdot 7 = 8 \cdot 4 = 8\frac{1}{2}$ nearly. This is the number of the centre crossing.

(*b*) 'Divide the radius of the siding curve by twice the gauge and extract its square root. The sq. root will be the number of the centre or sharpest crossing.'

Example :— The radius of the siding curve is 803. We then have

$$\sqrt{R \div 2G}$$

$$= \sqrt{803 \div 11}$$

$$= \sqrt{73} = 8\frac{1}{2} \text{ number of centre crossing.}$$

II. To fix the position of the centre or the sharpest crossing from springing of curve in a set of three-throws :—

(*a*) 'Multiply CL by $0 \cdot 709$'

The product will be the distance from the springing of curve to the theoretical nose of the centre crossing.

Example :— Let us assume that our main crossing is 1 in 12 and its curve lead is 132. We then have :—

$132 \times 0 \cdot 709 = 93\frac{1}{2}$ being the distance from springing of curve to theoretical point of the centre crossing.

(*b*) The distance from springing of curve to theoretical point of the centre crossing can also be found by the following:–

$N (G \times 1 \cdot 417)$

where N is 1 in 12 and G is $5 \cdot 5'$

$= 12 (5 \cdot 5 \times 1 \cdot 417)$

$= 12 \times 5 \cdot 5 \times 1 \cdot 417$

$=$ 93·5 feet being the distance from springing of curve to TNC of the centre crossing.

(*c*) The CL of 1 in $8\frac{1}{2}$ crossing by the usual formula $\frac{C^2}{2R}$ = versine can also be found out.

$$\frac{C^2}{2R} = \text{Versine} = 5 \cdot 5$$

conversely $2\ R \times \text{Versine} = C^2$

$\therefore \quad C^2 = 2 \times 803 \times 5 \cdot 5$

$\therefore \quad C = \sqrt{2 \times 803 \times 5 \cdot 5} = 93 \cdot 9$

$=$ 93′-10″ Curve lead.

SL, the switch lead of a 1 in 12 crossing is 33·6. Since the heels of switches of both the crossings 1 in 12 and 1 in $8\frac{1}{2}$ are at the same place, the distance from heel of switch to TNC of the 1 in $8\frac{1}{2}$ crossing is $93 \cdot 5 - 33 \cdot 6 = 59 \cdot 9$ = say 60 feet.

It will be seen that SL or switch lead of the 1 in $8\frac{1}{2}$ as also the 1 in 12 crossing in this case has been shown to be equal *i.e.* 33·6. The reason of

the smaller crossing having this long switch lead, is that the clearance at its heel of switch in this case is double the ordinary one *i.e.* $4\frac{1}{2}'' + 4\frac{1}{2}'' = 9''$. We can now find out how the SL comes to 33·6.

$$\text{Formula } \frac{C^2}{2R} = \text{Versine} = 9'' = 0\cdot75$$

$$\text{Conversely } 2\,R \times \text{Versine} = C^2$$

$$\text{therefore } \quad C^2 = 2 \times 803 \times 0\cdot75.$$

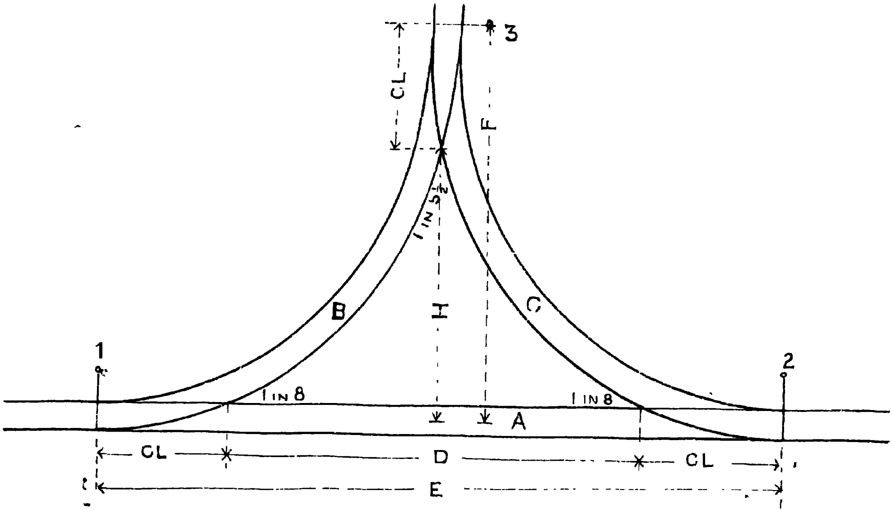
$$\therefore \quad C = \sqrt{2 \times 803 \times 0\cdot75} = 34 \text{ nearly}.$$

SL or switch lead of the 1 in $8\frac{1}{2}$ crossing in this case with the clearance at heel of switch being $9''$, is 34 feet nearly.

On the $5'$-$6''$ Gauge, we can lay the Three-throws with the following crossings :—

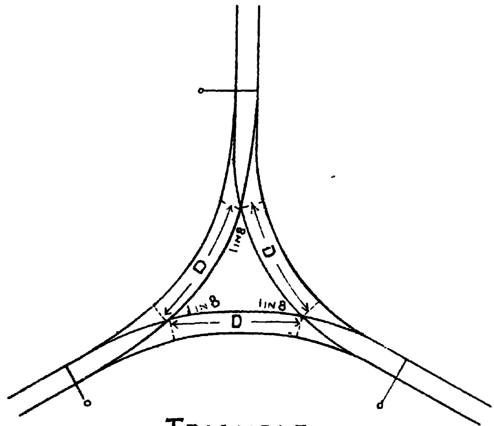
Main crossings.	Centre crossings.
1 in 12	1 in $8\frac{1}{2}$
1 in 10	1 in 7
1 in $8\frac{1}{2}$	1 in 6

Crossings on curves are of two kinds. First those formed by two curves running in opposite directions which are known as the curves of contrary flexure and secondly those formed by two curves running in similar direction which are known as curves of similar flexure. The lead of crossings is always the same whether the main track be straight or curved, whether the diverging line branches in the same or opposite direction to that of the main



TRIANGLE.

DIAGRAM No. 25.



TRIANGLE.

DIAGRAM No 26.

track; whatever the arrangement of the connection may be, the lead will always remain the same but this is not so with the curvature of the curve. When a crossing is put on the inside of a curve, it gives a much smaller radius than when placed on a straight line, while the reverse is the case when it is placed on the outside of a curve. When the turn-out is from the inside of a curve, its degree of curvature will be the sum of the degrees of the turn-out curve and the main line curve but when it is from the outside of a curve, its degree of curvature will be the difference between the degrees of the two curves. When the radii of two curves of contrary flexure are equal, each is very nearly equal to twice the radius of the same crossing when used on a straight track. Thus if a 1 in 8 crossing is used on a straight track, its radius is 712 feet but if the lines are curved in opposite directions, the radius is doubled, *i.e.*, 1424 feet.

---

27. Triangles.

Diagram Nos. 25 and 26.

At temporary termini, where Turn-tables will not ultimately be required, it is usual to put in triangles for reversing engines or vehicles. A triangle is a combination of three sets of points and crossings laid in the form of a triangle. Line A is usually a siding and lines B and C diverge from

it in such a manner that by running a vehicle over the triangle, it is reversed as completely as if it had been on a turn-table.

In diagram 25, the distance D between the TNC of the two crossings on the straight will be equal to 2R — G — 2CL.

The distance E between the tangent points of curves No. 1 and 2 will be equal to 2R — G.

The distance F from centre of line A to tangent point of curve No. 3 will be equal to R — $\frac{1}{2}$G.

The distance H from centre of line A to TNC of crossing No. 3 will be equal to R — $\frac{1}{2}$G — CL.

Example :—

Let us assume that our crossings No. 1 and 2 are 1 in 8 with a radius of 712 feet and CL 88 feet; and crossing No. 3 is 1 in 5$\frac{1}{2}$ with CL 60$\frac{1}{2}$ feet.

To find D the distance from TNC of crossing No. 1 to TNC of crossing No. 2.

$$\begin{aligned} D &= 2R - G - 2CL. \\ &= 2 \times 712 - 5\tfrac{1}{2} - 2 \times 88 \\ &= 1424 - 5\tfrac{1}{2} - 176 \\ &= 1242\tfrac{1}{2} \text{ feet.} \end{aligned}$$

To find E the distance from TP of curve No. 1 to TP of curve No. 2.

$$\begin{aligned} E &= 2R - G. \\ &= 2 \times 712 - 5\tfrac{1}{2} \\ &= 1424 - 5\tfrac{1}{2} \\ &= 1418\tfrac{1}{2} \text{ feet.} \end{aligned}$$

To find F the distance from centre of line A to TP of curve No. 3.

$$
\begin{aligned}
F &= R - \tfrac{1}{2}G \\
&= 712 - \tfrac{1}{2} \times 5\tfrac{1}{2} \\
&= 712 - 2\tfrac{3}{4}. \\
&= 709\tfrac{1}{4} \text{ feet.}
\end{aligned}
$$

It will be seen that distance F is exactly half of distance E.

To find H the distance from centre of line A to TNC of crossing No. 3.

$$
\begin{aligned}
H &= R - \tfrac{1}{2}G - CL. \\
&= 712 - \tfrac{1}{2} \times 5\tfrac{1}{2} - 60\tfrac{1}{2}. \\
&= 712 - 2\tfrac{3}{4} - 60\tfrac{1}{2}. \\
&= 648\tfrac{3}{4} \text{ feet.}
\end{aligned}
$$

In diagram No. 25, crossings No. 1 and 2 are 1 in 8 and crossing No. 3 is 1 in $5\frac{1}{2}$ but any combination of crossings may be used, the number of the centre crossing No. 3 being equal to the number of the main crossings No. 1 or 2 multiplied by 0·7. Thus if our main crossings on the straight are 1 in 8, 1 in $8\frac{1}{2}$, 1 in 10, or 1 in 12 respectively, crossing No. 3 in each case will be :—

Main crossings on straight.		Centre crossing. No. 3.
1 in 8 × 0·7 = 5·6	=	1 in $5\frac{1}{2}$
1 in $8\frac{1}{2}$ × 0·7 = 5·95	=	1 in 6
1 in 10 × 0·7 = 7	=	1 in 7
1 in 12 × 0·7 = 8·4	=	1 in $8\frac{1}{2}$

If the triangle is laid in as shown in the second figure (diagram No. 26) all the crossings will be of the same number and the radii of all the curves will be equal and there will be no straight track. The arrangement is equi-angular, each crossing having the same angle. It should also be noted that as each curve leaves the outside of another curve, the radii of the crossings are doubled. In this case D will be equal to R — (CL × 1·732).

To find D the distance from TNC of any one crossing to the TNC of any other crossing in the triangle :—

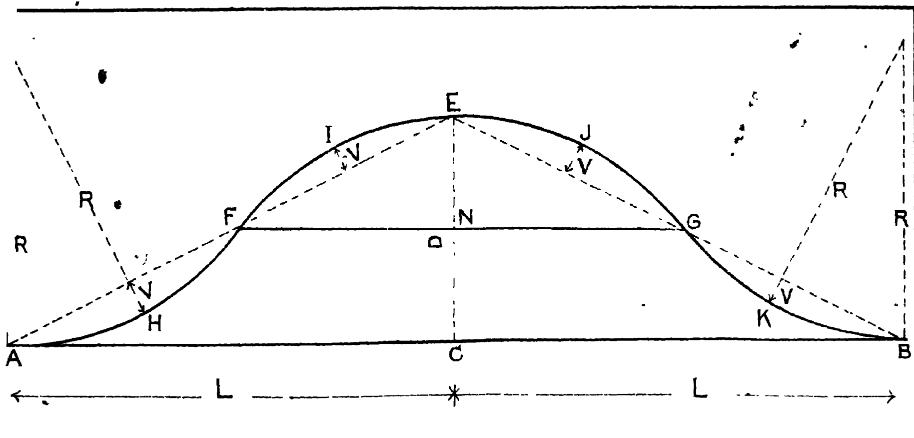
$$\begin{aligned} D &= R - (CL \times 1{\cdot}732) \\ &= 1424 - (88 \times 1{\cdot}732) \\ &= 1424 - 152{\cdot}416 \\ &= 1271{\cdot}584 = 1271\tfrac{1}{2} \text{ feet.} \end{aligned}$$

Triangles can only be laid in where there is plenty of space available in the yard but where it is not, turn-tables are laid in which serve the same purpose.

28. DIVERSIONS.

Diagram No. 27.

In cases of land slips, wash-aways, derailments or other obstructions on the line or when portions of a bridge have to be re-built, the line is tempo-



Diversion.

Diagram No. 27.

rarily diverted, a little distance away from its original position so as to pass the trains around the place of obstruction. A diversion usually consists of two reverse curves, the radii of which should be uniform and should in no case be less than the radius given by a 1 in 10 crossing. A radius of 2,000 feet is recommended. First of all, it should be decided how far the diversion line is to be laid from the main line. This of course depends on the nature of obstruction on the main line or the amount of room the main line will require for repairs, but once it is fixed, it also fixes the length of the diversion.

In diagram 27, ACB is a portion of main line in which C is the place of obstruction. AFEGB is the diversion line. CE is the centre of the diversion and D is the distance between the main and diverted line, centre to centre. F and G are the reversing points of the two curves AF and EF and EG and BG. L is the length of each half of the diversion. V is the versine of the curves AF, EF, EG and BG and R is the radius of the diversion curves.

Example :—

Let us now assume that we have to divert our line to 14 feet centres and the radius of our curve is 2000 feet.

(*a*) To find L the length of each half of the diversion :—

$$
\begin{aligned}
L &= \sqrt{D\,(4R-D)} \\
&= \sqrt{14\,(4\times 2000-14)} \\
&= \sqrt{14\,(8000-14)} \\
&= \sqrt{14\,(7986)} \\
&= \sqrt{111804} \\
&= 334 \text{ feet.}
\end{aligned}
$$

= 334.37

(*b*) Another method to find L the length of each half of the diversion.

$$
\begin{aligned}
L &= \sqrt{4R\,(D)-(D^2)\times 2} \\
&= \sqrt{4\times 2000\,\,(14)-(14^2)\times 2} \\
&= \sqrt{8000\,\,(14)-(196)\times 2} \\
&= \sqrt{8000\,\,(14)-(392)} \\
&= \sqrt{112000-392} \\
&= \sqrt{111608} \\
& \quad\; 334 \text{ feet.}
\end{aligned}
$$

: 334.06.

To find the length of the cords AF, EF, EG and BG.

$$
\begin{aligned}
\text{Cords} &= \sqrt{D\,R} \\
&= \sqrt{14\times 2000} \\
&= \sqrt{28000} \\
&= 167 \text{ feet.}
\end{aligned}
$$

To find V the versine of the curves AF, EF, EG and BG.

$$V = \frac{\text{Cord}^2}{8R}$$

$$= \frac{167 \times 167}{8 \times 2000}$$

$$= \frac{27889}{16000}$$

$$= 1\tfrac{3}{4} \text{ feet.}$$

$$FG = L$$

$$FN \text{ or } GN = \tfrac{1}{2}L$$

$$EN \text{ or } CN = \tfrac{1}{2}D$$

Diagram 27 shows a diversion laid with two reverse curves but sometimes a short tangent is introduced between them, but trains run smoother over a diversion if there is no tangent or a straight portion between the reverse curves.

Directions for laying out a diversion :—

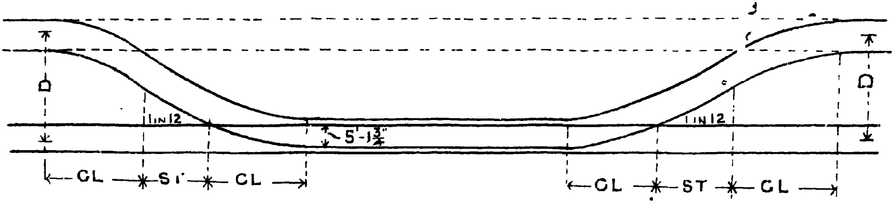
Drive a peg at C the place of obstruction. Run a tape from C to B equal to L and drive a peg at B. Similarly run the tape from C to A the other half of the diversion and drive a peg at A. From the point C at right angles to the line AB, lay off the offset CE equal to D and drive a peg at E. Run the tape from E to B and drive a peg at G the centre of the line EB. Similarly run the tape from E to A and drive a peg at F. Then find out the

versines of the curves AF, EF, EG and BG and drive pegs at H, I, J and K from the cords AF, EF, EG and BG. Then set out the diversion line AHFIEJGKB.

29. GANTLETTED TRACKS (DIVERSION).

Diagram No. 28.

A gantletted track is a sort of a temporary diversion on a double line of track without a pair of points so laid that one road is shifted from its original position and passes close by and through the other road with a crossing at either end but no sets of points. This arrangement is very economical and is used on bridges where half the bridge under one road requires opening out for grouting or other repairs. Two ordinary leads are put in and the straight portion in between the leads on the bridge is laid on with ordinary check chairs which take the two rails of the two roads separately. No sets of points are required but the lines have to be protected and trains passed over the gantletted track under Single line Block Rules or by Pilot system. The straight track laid on check chairs between the two leads can be of any required length which may be determined by the length of the bridge and any additional space required at either end of the bridge for purposes of stacking material or fixing any special plant for grouting.



GANTLETTED TRACK.
(DIVERSION)

DIAGRAM No. 28.

Any crossings may be used if the roads are on straight but if they are on curve, flat crossings giving pretty long leads are recommended to avoid sharp curves. 1 in 12 crossings may be used with advantage in all cases. It will be seen that there are no switches and that full curve lead is to be given to the crossing curves The gauge for the purposes of finding out the CL or curve lead in this case becomes 5′-1$\frac{3}{4}$″. *i.e.*, (5-′6″—1$\frac{3}{4}$″+2$\frac{1}{2}$″), 1$\frac{3}{4}$ in. being the clearance between the two rails and 2$\frac{1}{2}$ in. being the top width of one rail. If the roads are on curve, extra long check rails may be provided at the reversing point of the curve to guide the vehicles safely over the sharp portion and the crossings.

CHAPTER IV.

G. I. P. Railway Practice.

30. Structural Dimensions and Theoretical considerations of Permanent Way on G. I. P. Railway.

On the Great Indian Peninsula Railway, the following theoretical considerations and structural dimensions of Permanent Way are followed :—

(1) The circular curve of a turn-out is to start at the heel of switch and is to be tangential to that rail.

(2) There is to be short length of straight over the crossing. This is necessary as the crossing itself is too rigid to form part of the curve of turn-out. It is also desirable for easy running.

(3) The circular curve of the turn-out is to end a little in front of the crossing and is to be tangential to the short length of straight over the crossing.

The following table gives the structural dimensions of Permanent Way as observed on the G. I. P. Railway, 5′-6″ Gauge. The Plate-layer should note that if the methods of calculations differ on other Railways, there may be a little

difference but not a material one, in the results obtained. It would therefore be safe for him to follow the leads and radii as may have been laid down by his own railway.

Table showing structural dimensions of Points and Crossings observed on the G. I. P. Railway.

5′-6″ Gauge.

Section of rail. lbs.	Crossing number. 1 in —	Length of switch rail. feet.	Clearance at heel of switch. inches.	Distance from TNO to beginning of curve in front of crossing. feet.	Lead feet.	Radius feet.
.. 100	12	18	4½	5¾	94·90	1430
”	8½	18	4½	2	72·57	732
”	8½	12	4½	2	67·61	763
90	12	18	4½	3½	96·25	1485
”	9	18	4½	4	77·61	769
”	8½	15	4½	3½	69·50	713¼
82	12	18	4⅛	5½	97·19	1431
”	10	12	4⅛	3½	79·75	1134
”	8½	18	4⅛	2	73·93	733
”	8½	12	4⅛	2	69·21	759
”	8	12	4⅛	2	67·00	705
80	12	15	4⅛	5½	93·69	1468
”	8½	15	4⅛	3¼	71·00	720
”	8½	12	4⅛	3¼	68·32	736
69	12	18	4⅛	5½	94·75	1347
”	10	12	4⅛	3½	79·75	1134
”	8½	12	4⅛	2	69·21	759
”	8	12	4⅛	2	67·00	705

There is still an amount of second class 69 lbs. material for turn-outs on hand, the crossings of which are 1 in 8, 8½, 10 and 12. This material is to be used up in yards and for convenience of future substitution with 80 or 82 lbs. material, it is to be laid to the same leads as 80 and 82 lbs. respectively, the lead for 1 in 8 and 10 crossings is to be that for 1 in 8½. The radius of turn-out will be that necessary for the lead.

1 in 12 and 1 in 8½ are the Standard crossings on the G. I. P. Railway.

31. Length and details of crossings in use on the G. I. P. Railway.

Section of rail lbs.	Number of crossing 1 in —	Acute or obtuse.	Length of crossing.			Angle of crossing.		
			From heel to TNC.	From TNC to Toe.	Full length.			
100	4¼	acute	12′-0″	7′-10$\frac{9}{16}$″	19′-10$\frac{9}{16}$″	13°	26′	4″
,,	6	,,	10-9	9-6	20-3	9	33	00
,,	8½	,,	11-0	9-3	20-3	6	43	59
,,	12	,,	14-6	9-0	23-6	4	46	19
,,	4¼	obtuse	....	....	15-9	13	26	4
,,	6	,,	....	....	20-0	9	33	00
,,	8½	,,	....	....	24-0	6	43	59
90	9	,,	....	....	25-6¾	6	22	00
,,	8½	acute	13-1½	8-6	21-7½	6	43	59
,,	9	,,	11-5¼	6-0¾	17-6	6	22	00
,,	12	,,	11-7½	5-10½	17-6	4	46	19

31. Length and details of crossings in use on the G. I. P. Railway.—*contd.*

Section of rail lbs.	Number of crossing 1 in —	Acute or obtuse.	Length of crossing.			Angle of crossing.		
			From heel to TNC.	From TNC to Toe.	Full length.			
82	$4\frac{1}{4}$	acute	$10\text{-}2\frac{25}{64}''$	$11\text{-}6\frac{1}{4}''$	$21\text{-}8\frac{41}{64}''$	13°	26′	4″
,,	6	,,	11-4	11-4	22-8	9	33	00
,,	8	,,	10-6	11-2	21-8	7	9	72
,,	$8\frac{1}{2}$	,,	10-9	$11\text{-}1\frac{3}{8}$	$21\text{-}10\frac{3}{8}$	6	43	59
,,	10	,,	12-6	11-0	23-6	5	43	77
,,	12	,,	14-6	9-0	23-6	4	46	19
,,	$4\frac{1}{4}$	obtuse	....	....	19-3	13	26	4
,,	6	,,	....	....	20-0	9	33	00
,,	$8\frac{1}{2}$	,,	....	....	20-5	6	43	59
69	8	acute	10-6	11-2	21-8	7	9	72
,,	10	,,	12-6	11-0	23-6	5	43	77
,,	12	,,	14-6	9-0	23-6	4	46	19
,,	6	,,	reversible	and solid.	5-0	9	33	00
,,	8	,,	,,	,,	6-0	7	9	72
,,	10	,,	,,	,,	7-3	5	43	77

32. Properties of rail sections in use on the G. I. P. Ry.

Section & description of rails.	Height of rail inches.	Width of top of rail inches.	Width of base of rail inches.	Thickness of web inches.	Area of Section inches.
100 lbs. B.H. B.S. G.I.P.	$5\frac{29}{32}$	$2\frac{3}{4}$	..	$\frac{3}{4}$	9·82
90 „ F.F. B.S. No. 90 R.G.I.P.	$5\frac{5}{8}$	$2\frac{5}{8}$	$5\frac{3}{8}$	$\frac{35}{64}$	8·83
82 „ B H. .. G.I.P.	$5\frac{1}{2}$	$2\frac{3}{8}$	..	$\frac{5}{8}$	8·03
69 „ D.H. .. G.I.P.	5	$2\frac{7}{16}$	$2\frac{7}{16}$	$\frac{5}{8}$	6·77
90 „ F.F. B.S. A.D.C.	$5\frac{3}{8}$	$2\frac{5}{8}$	$5\frac{3}{8}$	$\frac{9}{16}$	—
87 „ F.F. .. B.K.	$5\frac{3}{20}$	..	..	..	8·53
85 „ B.H. .. A.D.C.	$5\frac{35}{64}$	$2\frac{45}{64}$	$2\frac{1}{2}$	$\frac{41}{64}$	8·33
80 „ F.F. .. I.M.	$5\frac{1}{16}$	$2\frac{13}{32}$	4	$\frac{9}{16}$	7·84
75 „ F.F. .. I.S.	$4\frac{13}{16}$	$2\frac{7}{16}$	$4\frac{13}{16}$	$\frac{17}{32}$	7·35
62 „ F.F. .. I.S.	$4\frac{1}{2}$	..	..	..	6·08

32. Properties of rail sections in use on the G. I. P. Ry.—*contd.*

Section & description of rails.	Height of rail inches.	Width of top of rail inches.	Width of base of rail inches.	Thickness of web inches.	Area of Section inches.
100 lbs. F.F. B.S. E.I.R.	$5\frac{3}{4}$	$2\frac{3}{4}$	$5\frac{3}{4}$	$\frac{37}{64}$	..
100 „ D.H. .. E.I.R.	6	$2\frac{3}{4}$	$2\frac{3}{4}$	$\frac{9}{16}$	..
$93\frac{1}{2}$ „ F.F. .. E.I.R.	$5\frac{1}{4}$	$2\frac{3}{4}$	$5\frac{1}{4}$	$\frac{9}{16}$	..
90 „ F.F. .. E.I.R.	$5\frac{5}{16}$	$2\frac{45}{64}$	5	$\frac{41}{64}$	..
$88\frac{1}{2}$ „ B.H. .. E.I.R.	$5\frac{45}{64}$	$2\frac{45}{64}$	$2\frac{1}{2}$	$\frac{41}{64}$	..
75 „ D.H. .. E.I.R.	$5\frac{3}{16}$	$2\frac{3}{8}$	$2\frac{3}{8}$	$\frac{3}{4}$	..
74 „ F.F. .. E.I.R.	$4\frac{3}{4}$	$2\frac{3}{8}$	4	$\frac{3}{4}$	..
35 „ F.F. B.S. No. 35 C.P.	$3\frac{1}{4}$	..	..	..	3·43

33. Permissible wear of rails on G. I. P. Railway.

The limit of wear on straight track under ordinary conditions is about 23 per cent. of the head or about 0·40 inch to 0·45 inch vertical wear. The permissible wear for the different section of rails in use on the G. I. P. Railway is tabulated below :—

Weight of rail per yard lbs.	Weight of head per yard lbs.	Permissible wear in lbs. per yard.	Representing Vertical wear of about inches.
100	50	12·5	0·45
90	37¾	9·4	0·37
85	38½	9·5	0·35
82	40	10·0	0·42
80	39	9·75	0·41
75	34½	9·6	0·41
69	26½	6·0	0·26

In 69 lbs. rails the limit of vertical wear is about ¼ inch representing about 5 lbs. When the wear exceeds this limit, worn flanges are liable to strike the fish-plates. This rule presumes that the loss of weight occurs in the head only and is due to wear. In certain conditions such as when cinder ballast is used or in wet tunnels, serious corrosion may take place and rails may have to be

removed long before serious wear of the head has taken place. Double headed rails may of course be worn on both heads being invertible. On sharp curves, serious side wear of the head occurs. When one side of the head is worn, the rail can be turned, end for end, so as to present a new face for wear. Generally the 100 lbs. rail will have to be renewed when the loss is about 15 lbs. per yard from side wear on the head and in rails of other sections after about 15 per cent. reduction in weight (15 per cent. of the total weight).

Wear of rails is under observation and although no hard and fast rules are laid down, the above table based on the data so far available will serve as a guide.

34. Junction fish-plates and planed rails on G. I. P. Railway.

Amateur and inexperienced plate-layers have sometimes a great difficulty in distinguishing one junction fish-plate from another and have to experiment several fish-plates before they pick out the right one. Usually the junction fish-plates bear marks showing the inside or outside and right or left, also the section of the two rails to be joined but at times we get a shop-made supply when they do not bear such distinguishing marks. To pick out a correct plate is then a real difficulty unless one knows how to do so. I therefore

explain below how this can be done :—

2. As the height as also the thickness of web of the various rail sections in many cases differ, special fish-plates have to be made to join such rails. These are called junction fish-plates. Where both the height and thickness of web of the two rails to be joined differ, the junction fish-plates are so designed that when two such rails of varying height and thickness are fished, their tops and the inner or running edges come level and flush. The design of the junction fish-plate has therefore to allow for the differing heights and thickness of such rails. Since the inner or running edges of any two rails of varying thickness when fished must be flush, the inside plates must necessarily be flat and fit the webs of the two rails in one flat plane but this is not so on the outside, where the extra thickness of web of the heavier rail projects beyond that of the lighter rail. It therefore follows that the outer fish-plate must be made to fit the projected thickness of the heavier rail and hence it cannot be flat like the inside plate but has a bulge in it. The easiest way to distinguish the inside fish-plates from the outside ones is, that all inside fish-plates have a flat plane inner surface while the outside ones have a bulge to suit the extra thickness of the heavier rail. We now

know that the fish-plate having a plane inner surface is an inside fish-plate and the one with a bulge on its inner surface is an outside one.

3. The design has also to surmount the difficulty of the varying heights so as to bring the tops of two rails of varying height to one level. This is secured by notching the top edges of the fish-plates suitably. It should be noted that the higher edge of the fish-plate will fit the lighter rail so as to lift it to the level of the heavier rail and that the lower or notched edge of the fish-plate will fit the heavier rail. The fish-plates are therefore properly notched to suit the inside and outside as also the right and left hand rails and are described as below :—

"Inside left and outside left."

"Inside right and outside right."

They must therefore be fitted in their proper places so as to get both the top of the rails and inner edges level and flush. If by mistake we fix a right hand pair in the place of a left hand one and *vice versa*, the top tables of the two rails will not come in one level but the bottom ones will, with the result that the extra height of the heavier rail over the lighter one will be clearly seen on the top surface and wheels will drop over the joint with a thud.

4. Similarly if an inside plate is placed on the outside and *vice versa*, the same will be the result besides the running edges will not be in one plane. If again, the outside right plate is placed on the inside left and *vice versa*, it will fit in, the top tables will also be level but not the running flanges which will cause the extra thickness of the heavier rail to project over the lighter one on the inner or running side causing a kink and the wheel flanges will kick against it until it is either thoroughly worn out or chipped off by the wheel flanges. It is needless to say that this is dangerous to Traffic as it might cause a flange to mount it and cause a derailment. It is therefore absolutely necessary to fix these plates in the places for which they are designed and no alteration can be made.

5. We have now to learn how to distinguish the right hand plates from the left hand ones. Unfortunately no hard and fast rule can be laid down in this case but generally viewing a joint from the heavier rail to the lighter one, we have a right-hand plate on the right and a left-hand one on the left but this does not apply in all cases nor does it apply to junction fish-plates of rails having

equal thickness of web. To avoid misunderstanding, the following sketch is given showing the direction of the view and the right and left-hand sides.

1 100 lbs. O L 82 lbs.

I L

——>Direction of view.

I R

100 lbs. O R 82 lbs.

2 90 lbs. O L 82 lbs.

I L

——>Direction of view.

I R

90 lbs. O R 82 lbs.

3 90 lbs. O L 100 lbs.

I L

——>Direction of view.

I R

90 lbs. O R 100 lbs.

6. In the above paragraphs, I have dwelt at length on the junction fish-plates of rails having different heights and thickness but in cases where

the thickness of web of both the rails is the same and only the height differs, the matter is simplified, both the inner and outer plates have a flat plane surface and there are no right or left-hand plates. The same pair can be fixed to either hand rail by simply changing the plates suitably, *i.e.*, if the pair of fish-plates fixed on the inner rail has to be fixed on the outer one, it could be done by using the outside plate on the inside and the inside plate on the outside. V and X type fish-plates for joining the 82 lbs. rails to 69 lbs. rails are of this type and can be used on either the inner or outer rail by simply changing their position as described.

7. Where junction fish-plates are not used, planed rails are used which serve the same purpose. These are 15 or 18 feet in length, one end is of its original section and the other planed off to the height and thickness of the lighter rail section to which it is to be joined. For instance we have to join a 100 lbs. section rail to a 82 lbs. section rail. A piece of 100 lbs. section rail 18 feet in length is then planed off with one end left as it originally was and the other end reduced to the height and thickness of the 82 lbs. rail, the original end taking 100 lbs. fish-plates and the reduced end taking 82 lbs. fish-plates. Unless the planing is carefully done, the planed rails make unsatisfactory joints.

35. (*a*) Weights of P. W. and fencing material in use on Indian Midland Section of G. I. P. Ry.

Description.	No. per ton.	No. per mile.	Weight.	
			Unit.	Lbs.
Rails, steel, 30 ft. long, 80 lbs. per yard F.F.	2·800	352	Each	800·00
Fish-plates, steel, 5 holed (2 to a 30 feet rail).	124·444	704	,,	18·00
Fish-bolts and nuts, 5 holed plates with 30 feet rails.	1280·00	1,760	,,	1·75
Sleepers, cast-iron, pot, oval with iron seats.	24·447	3872	,,	91·625
Tie bars, wrought-iron, 2″ wide	84·528	1936	,,	26·50
Cotters ,, 2″ ,, ...	4307·692	3872	,,	0·52
Gibs ,, 2″ ,, ...	8960·000	3872	,,	0·25
Jaws or fastenings	1237·569	3872	,,	1·81
Keys, wrought-iron	2000·000	3872	,,	1·12
Steel creep pins (4 to a 30 feet rail)	14000·000	1408	,,	1·16
Rests, felt (2 to a pot sleeper)	4536·0	15488	,,	0·0617
Sleepers, teak, rectangular	14·00	1936	,,	160·00
,, sal	11·27	1936	,,	191·00
,, deodar	21·334	1936	,,	105·00
,, creosoted pine	18·361	1936	,,	122·00
,, jarrah..	12·655	1936	,,	177·00
Spikes, dog, $5\frac{3}{4}'' \times \frac{3}{4}''$ (4 to a sleeper) ..	3000	7744	,,	0·746

Description.	No. per mile.	Weight of each.			
		Tons.	cwt.	qr.	lbs.
Posts, straining	16	0	2	1	8·5
Do. stiffening	100	0	0	1	7·5
Do. W. I. intermediate for Screw bases ..	940	0	0	0	11·5
Bases pointed C. I. 1′-11″ long for I. posts..	570	0	0	0	19·16
Do. screw 3′ long for I. posts	570	0	0	1	2
Wedges, W. I...	1,140	0	0	0	0·41
Bolts, straining with 2 nuts and washers ..	160	0	0	0	2·75
Keys, fluted G. I.	570	0	0	0	2 per 100
Wire, galvanized, iron, in coils of 450 yards.	20	0	2	0	4

35. (*b*) Weights of P. W. & Fencing material in use on G. I. P. Ry.

Description.	No. per ton.	No. per mile.	Weight. Unit.	Weight. lbs.
Rails, steel, bull-headed 100 lbs. 30′-0″ long.	2·24	352	Each	1000·0
,, ,, ,, 33′-0″ ,,	2·0364	320	,,	1100·0
,, ,, ,, 35′-7½″ ,,	1·8863	296	,,	1187·5
,, ,, ,, 36′-0″ ,,	1·866	293⅓	,,	1200·0
,, ,, 82 lbs. 30′-0″ ,,	2·7317	352	,,	820·0
,, ,, ,, 33′-0″ ,,	2·4833	320	,,	902·0
,, ,, ,, 35′-7½″ ,,	2·3004	296	,,	973·75
,, ,, ,, 36′-0″ ,,	2·2764	293⅓	,,	984·0
Fish plates, steel, with flanged bottom 4-holed for 100 lbs. rail.	96·3	587	,,	23·25
Fish plates, steel, ordinary, 4-holed for 100 lbs. rails.	142·2	587	,,	15·75
Fish plates, steel, 5-holed, 'W' type 22″ long (with 36 ft. rails) 82 lbs.	94·7	587	,,	23·65
Fish plates, steel, 5-holed, 'W' type 22″ long (with 30 ft. rails) 82 lbs.	94·7	704	,,	23·65

Fish plates, steel, 5-holed, 'W' type 22" long (with 27 ft. rails) 82 lbs.	94·7	782	,,	23·65
Fish bolts, nuts and washers for 100 lbs. rail 5" × $\frac{15"}{16}$.	1031·4	1174	,,	2·172
Fish bolts, nuts and washers 4½" × ⅞" (5-holed plates with 36 ft. rails) 82 lbs.	1357·0	1467	..	1·65
Fish bolts, nuts and washers 4½" × ⅞" (5-holed plates with 30 ft. rails) 82 lbs.	1357·0	1760	,,	1·65
Fish bolts, nuts and washers 4½" × ⅞" (5-holed plates with 27 ft. rails) 82 lbs.	1357·0	1955	,,	1·65
Pots, cast iron, round for 100 lbs. rails (14 sleepers per 36 ft. rail).	18·66	4107	,,	120·0
Pots, cast iron, for 100 lbs. rails (14 sleepers per 36 ft. rail).	18·66	4107	,,	120·0
Pots, cast iron, oval, for 82 lbs. rails (12 sleepers per 36 ft. rail).	22·17	3520	,,	101·0
Pots, cast iron, oval, for 82 lbs. rails (14 sleepers per 36 ft. rail).	22·17	4107	,,	101·0
Pots, cast iron, special joint for 100 lbs. B.H. Rails.	15·55	587	,,	144·0
Pots, cast iron, special joint for 82 lbs. B. H. Rails.	16·97	587	,,	132·0
Tie bars, special for joint pots 100 lbs. ..	83·0	294	,,	27·0
Tie bars, special for joint pots 82 lbs. ..	83·0	294	,,	27·0
,, for 100 lbs. rail (14 sleepers per 36 ft. rail.)	87·0	2053	,,	25·75

35. (*b*) Weights of P. W. & Fencing material in use on G. I. P. Ry.—*contd.*

Description.	No. per ton.	No. per mile.	Weight.	
			Unit.	lbs.
Tie bars 2″ for 82 lbs. rails (12 sleepers per 36 ft. rail).	87·0	1760	Each	25·75
,, ,, ,, (14 ,, ,,).	87·0	2053	,,	25·75
Cotters, for 100 lbs. rails (14 ,, ,,).	4480·0	4107	,,	0·522
,, for 82 lbs. ,, (12 ,, ,,).	4480·0	3520	,,	0·522
,, ,, ,, (14 ,, ,,).	4480·0	4107	,,	0·522
Gibs, for 100 lb. rails (14 sleepers per 36 ft. rail).	10228·0	4107	,,	0·235
Gibs, for 82 lb. rails (12 sleepers per 36 ft. rail).	10228·0	3520	,,	0·235
Gibs, for 82 lb. rails (14 sleepers per 36 ft. rail).	10228·0	4107	,,	0·235
Rests, cast iron, for old pattern pots (12 sleepers per 36 ft. rail).	624·0	7040	,,	3·59
Rests, cast iron, for old pattern pots (14 sleepers per 36 ft. rail).	624·0	8214	,,	3·59

Chairs 4-holed 100 lb. ordinary R. & L. ..	43·49	....	,,	51·50
,, ,, 82 lb. rails ordinary R. & L.	64·0	4107	,,	35·0
,, 2-holed C. I. for 100 lbs.	43·08	4107	,,	52·0
,, slide 4-holed 100 lbs.	38·62	....	,,	58·0
,, ,, ,, 82 lbs.	43·07	....	,,	52·0
,, check ,, 100 lbs.	27·31	....	,,	82·0
,, ,, ,, 82 lbs.	37·33	....	,,	60·0
Steel bolts, with square nuts and washers $\frac{7}{8}''$ dia. $8\frac{3}{4}''$ long over all for 100 lb. rails.	685·0	8214	,,	3·27
Spikes, $\frac{3}{4}''$ for 82 lbs. section rails.	2333·0	16428	,,	0·96
Keys, wood (Teak)	2604·0	4107	,,	0·86
Keys, steel coiled (12 sleepers per 33 feet rail) 82 lbs. rails	1080·0	3520	,,	2·08
Keys, steel (14 sleepers per 36 feet rail) ..	1080·0	4107	,,	2·08
,, for 100 lbs. rails	670·0	4107	,,	3·344
Rails, steel 90 lbs. flat-footed, 30′-0″ long..	2·488	352	,,	900
,, ,, ,, 33′-0″ ,,	2·262	320	,,	990
,, ,, ,, 35′-7½″ ,,	2·095	296	,,	1068·75
,, ,, ,, 36′-0″ ,,	2·074	293⅓	,,	1080
Fish-plates, flat-footed, 90 lbs. section ..	132·7407	587	,,	16·875
Fish-bolts and nuts 90 lbs. section	1029·8851	1174	,,	2·175
Sleepers, pressed steel, 90 lbs. Section ..	14·6405	2053	,,	153·000
Distance pieces, steel, 90 lbs. Section ..	1600·0000	4107	,,	1·400
Keys, steel, 90 lbs. Section	1317·6471	4107	,,	1·700

Description.	No. per mile.	Weight of each.			
		Tons.	cwt.	qr.	lbs.
Posts, straining C. I.	14	0	1	2	26
,, Intermediate W. I.	587	0	0	0	13·68
Bases, Screw C. I. 3 ft. long.	587	0	0	1	2·3
Wedges, W. I.	587	0	0	0	0·51
Bolts & nuts straining	140	0	0	0	2·34
Keys, fluted	600	0	0	0	2·0%
Wire, galvanized iron, 7 Strand 440 yards (1 bundle)	20	0	2	0	4

36. Super-elevation and Gauge on Curves on G. I. P. Railway.

Super-elevation or cant as it is commonly called means the height of the outer rail above the level of the inner one on any curve. The formula for finding out super-elevation for curves as given by Moleswortlı is $W \times \frac{\text{velocity}^2}{1 \cdot 25\ R}$ where W is the width of gauge. The result will give the cant or elevation in inches. As a great elevation of the outer rail over the inner one is liable to displace the load of trucks besides being disagreeable to passengers, a limit of approximately one-tenth of the gauge is the maximum elevation ever allowed. If the curves are very sharp necessitating more elevation than the one-tenth limit, it is essential to reduce the speed of trains for safety. On the next page is a table of super-elevation used on the G. I. P. Railway System. It is based on 45 miles velocity and 5′-6″ Gauge. It will be seen from the table that for all curves of 1700 feet and less radii, the cant is shown as 5″ which is the maximum permitted on the G. I. P. Railway. Most Railways have their own tables of cant or super-elevation based on conditions and circumstances prevailing thereon and the Plate-layer should therefore follow the table in force on his Railway. The formula will however give him an idea of how the cant or super-elevation is arrived at.

Example:—

$$W \times \frac{\text{velocity}^2}{1 \cdot 25\, R} = \text{Cant in inches.}$$

Where W is $5\frac{1}{2}$ feet,

Velocity is 45 miles per hour,

R is 1980 feet.

$$= \quad 5\tfrac{1}{2} \times \frac{45 \times 45}{1 \cdot 25 \times 1980}$$

$$= \quad \frac{11}{2} \times \frac{2025}{2475}$$

$$= \quad 4\tfrac{1}{2} \text{ inches cant.}$$

Table of cant or super-elevation used on curves on main line and ghats on the G. I. P. Ry.

Degree of curve.	Radius of curve in. Feet.	Radius of curve in. Chains.	Cant in inches.	Main line. Maximum permissible speed in miles per hour.	Ghat. Cant in inches.
0° – 30′	11459	..	$\frac{3}{4}$	unrestricted	$\frac{5}{16}$
	10560	160	$\frac{7}{8}$	,,	$\frac{3}{8}$
	7920	120	$1\frac{1}{8}$	,,	$\frac{1}{2}$
	6600	100	$1\frac{3}{8}$	,,	$\frac{5}{8}$
1 – 00	5730	..	$1\frac{1}{2}$	,,	$\frac{11}{16}$
	5280	80	$1\frac{5}{8}$	,,	$\frac{3}{4}$
	4620	70	$1\frac{7}{8}$	,,	$\frac{7}{8}$
	3960	60	$2\frac{1}{4}$	,,	1
1 – 30	3820	..	$2\frac{3}{8}$	,,	$1\frac{1}{8}$
	3300	50	$2\frac{5}{8}$	,,	$1\frac{1}{4}$
2 – 00	2865	..	$3\frac{1}{8}$	,,	$1\frac{3}{8}$
	2640	40	$3\frac{3}{8}$	64	$1\frac{1}{2}$
2 – 30	2292	..	$3\frac{7}{8}$	59	$1\frac{3}{4}$
	1980	30	$4\frac{1}{2}$	55	2
3 – 00	1910	..	$4\frac{5}{8}$	54	$2\frac{1}{8}$
	1650	25	5	51	$2\frac{3}{8}$
3 – 30	1637	..	5	50	$2\frac{1}{2}$
4 – 00	1433	..	5	47	$2\frac{3}{4}$
	1320	20	5	45	3
4 – 30	1273	..	5	44	$3\frac{1}{8}$
	990	15	5	39	4

Note to the table of cant or super-elevation :—

(*a*) Safe maximum speed in miles per hour $= 1 \cdot 25 \times \sqrt{R}$ in feet.

(*b*) Maximum speed allowed on Ghats is 25 miles per hour, the cant is calculated for a speed of 30 miles per hour in order to reduce the risk of runaway vehicles overturning.

Super-elevation of outer Rail on Curve.

(1) The inner rail of the curve represents rail level and adjustments for super-elevation in accordance with the table should be made in the outer rail.

(2) The full super-elevation should be given from end to end of circular curves and where transition curves are not used, should be run out on the straight at the rate of ½ inch in 30 feet. Where transition curves are used, super-elevation should decrease uniformly along the transition curve.

(3) Cant stones should be placed at tangent points and in long curves, intermediate stones 200 yards apart should be added. Square stones should be placed at the end of the run out. On transition curves, a smaller cant stone should be placed opposite the middle of the transition curve indicating half the super-elevation of the circular curve.

(4) The maximum permissible cant is 5 inches.

(5) In sidings, triangles etc., where the speed of trains is slow, the maximum permissible cant is 1 inch.

(6) Standard gauge should be used on curves of greater radius than 1,700 feet. On curves of 1,700 feet radius and less, gauge is to be $\frac{5}{16}$th inch or $\frac{3}{8}$th inch slack. ($\frac{5}{16}$th inch for 82 and 100 lbs. track and $\frac{3}{8}$th inch for 90 lbs. track.)

(7) No super-elevation or cant is to be given on Points and Crossings. On straight road, both the main track and the turn-out will be on level. If the main track is on curve, it will have its own super-elevation according to its radius and the turn-out will be laid on the same sleepers with whatever cant it may get according to the main track. Since no cant is to be given to turn-outs, no notching of sleepers is allowed.

CHAPTER V.

Curves.

37. Cut rails on curves.

(*a*) As the length of the outer rail of a curve is greater than that of the inner one, the rails used on the inside of a curve should necessarily be shorter than the outside in order to keep the joints square. If short rails are not used on the inside of a curve, the inner rail joints will get ahead of the outer joints. When this lead is as much as $2\frac{1}{4}$ inches, a rail cut $4\frac{1}{2}''$ shorter should be put in on the inner side. This will throw the inner joint $2\frac{1}{4}$ inches behind the outer and twice the former length will have to be covered before the lead of the inner joint is again as much as $2\frac{1}{4}$ inches ahead over the outer joint when another cut or short rail will be required.

The formula for calculating the number of cut rails (a cut rail being $4\frac{1}{2}$ inches less than the ordinary rail) is :—

$$N = \frac{15 \times L}{R} = \text{Number of cut rails required.}$$

Where N = Number of cut rails required.

L = Length of curve in feet.

R = Radius of curve in feet.

Example:—

Radius of curve is 7920 feet
Length of curve is 3696 feet

therefore

$N = \frac{15 \times 3696}{7920}$ = 7 cut rails required for this curve.

(*b*) The number of cut rails required for a curve can also be found by the formula $\frac{G+W}{R} \times L$

Where G = Gauge.
W = Width of top of rail.
R = Radius of curve in feet.
L = Length of curve in feet.

Let us assume that :—
G = 5·5 feet.
W = $2\frac{1}{2}$ inches = 0·2083 feet.
R = 7920 feet.
L = 3696 feet.

The inner rail of the curve should therefore be shorter than the outer rail to the extent of $\frac{G+W}{R} \times L$

$$= \frac{5{\cdot}5 + 0{\cdot}2083}{7920} \times \frac{3696}{1}$$

$$= \frac{5{\cdot}7083}{7920} \times \frac{3696}{1} = 2{\cdot}6638 \text{ feet.}$$

$$= 2'\text{-}7'' = 31 \text{ inches.}$$

As each cut rail is $4\frac{1}{2}$ inches short, the number of cut rails required is $= 31 \div 4\frac{1}{2} = 7$. This is the number of cut rails required for this curve.

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38. TO SET OUT A CURVE BY OFFSETS FROM THE TANGENT OR SPRINGING OF CURVE.

Diagram No. 29.

In diagram 29, produce the tangent line by placing poles or pegs 100 feet apart as shown in the diagram. The offsets can then be found out as follows :—

"Square the distance set off on the tangent line and divide the product by twice the radius of the curve. The result will be the required offset."

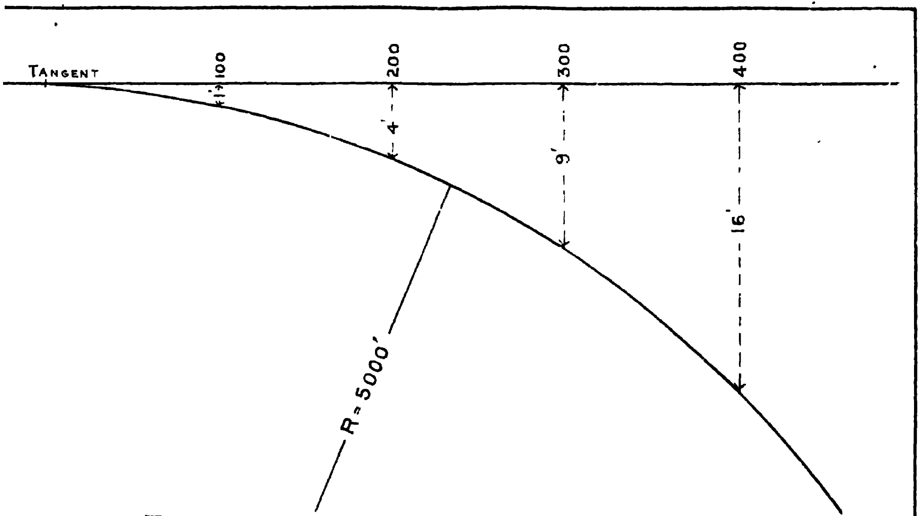
Example :—

Let us assume that our distance or cord at which the offset is required is 100 feet and the radius of the curve is 5000 feet.

The offsets at each of the 100 feet marks as shown on the diagram will therefore be=

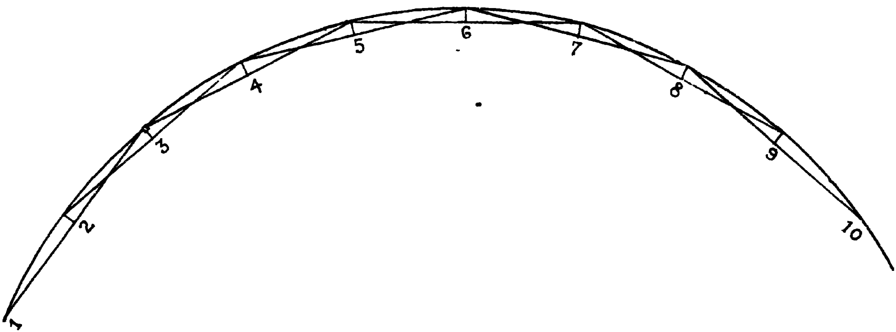
$$\frac{\text{Cord}^2}{2R} = \frac{100^2}{2 \times 5000} = \frac{10000}{10000} = \begin{matrix}\text{offset} \\ \text{1 foot.}\end{matrix}$$

$$\frac{\text{Cord}^2}{2R} = \frac{200^2}{2 \times 5000} = \frac{40000}{10000} = \text{4 feet.}$$



TO SET OUT A CURVE BY OFFSETS.

DIAGRAM No. 29.



RE-ALIGNING A CURVE.

DIAGRAM No. 30.

$$\frac{\text{Cord}^2}{2R} = \frac{300^2}{2 \times 5000} = \frac{90000}{10000} = 9 \text{ feet.}$$

$$\frac{\text{Cord}^2}{2R} = \frac{400^2}{2 \times 5000} = \frac{160000}{10000} = 16 \text{ feet.}$$

The poles or pegs may be placed at any required distance taking care that they are in a straight line.

39. Realigning Curves.

Diagram No. 30.

Due to oscillation of trains while passing round curves, where the road is not sufficiently ballasted and boxed and also due to constant packing and slewing, the curves originally laid to a certain radius often get out of alignment, the curvature varies and kinks are formed in the road which causes bad running round curves. The train sways from side to side and unpleasant running is the result. The only remedy is to re-align the curve from beginning to end giving an uniform curvature. This is done by a simple practical method explained below :—

Three Tee squares are used for the purpose of correctly re-aligning any curve. Two of these Tee squares are painted black and the third painted red. The two black ones are so notched that when the squares are fitted to the rail, the notch

packing and ballasting. If a train has to be passed during the progress of the work, it should be brought to a standstill short of the work and then allowed to pass dead-slow, after roughly tapering and packing the road. At times a train puts the curve back to its old alignment if the road is not well packed and ballasted.

Usually two turns of slewing will bring most curves into proper alignment but if the curve is very badly out, the slewing will have to be repeated 3 or 4 times before the proper curvature is attained. When the curve is so slewed and correct curvature is found right throughout its length, rail pegs about 3 or 4 feet in length, should be put in, in the centre of the track at each Tangent point and at every 100 feet of the length of the curve. The rail pegs should have a chisel-cut on the top at exact centre, which should correspond to the centre of the track. The gang Muccadum should then be instructed to check these centre pegs once a month and see if they are exactly in the centre of the road. If not, he should slew the curve to suit.

This is a very simple method of realigning any curve which looks or runs bad and the Plate-layer can do it himself without fear of getting wrong. At times the curve needs slewing to the right and at the very next point, to the left but this is due to

the distorted condition of the curve and if the process is carefully followed, a beautiful and uniformly realigned curve is the result. There are other methods, perhaps better than the one explained above, but they need the plotting of curves and evolving a new curve out of the old one but as the Plate-layer or the P. W. I. is mostly a practical man, he need not worry himself about these other methods unless they are worked out by the Engineer and correct measurements or pegs are given to him. It is therefore safe for him to rely on himself and follow this practical method which requires no calculations except for finding out the correct versine for that particular curve, which is easily done as explained.

CHAPTER VI.

Miscellaneous.

40. Definitions of Elementary Geometry.

Geometry, in the express sense of the word, means the art of measuring the Earth.

Trigonometry is that branch of mathematical science which is employed in calculating the sides and angles of a triangle and its doctrines are founded on the mutual proportions which subsist between its sides and angles.

Angle (from the word angulus a corner) is the inclination of two straight lines to each other, which meet together but are not in the same straight line. In other words, an angle is the amount of opening between two straight lines which meet in a point and is expressed as a quantity by stating how many parts of a right angle it contains, those parts being the degree, the minute and the second.

The circumference of every geometrical circle is supposed to be divided into 360 degrees, each degree into 60 minutes and each minute into 60 seconds. Each circle contains 4 right angles and each right angle therefore contains 90 degrees.

A Plate-layer often comes across many geometrical terms. To enable him to understand their

meaning, a few geometrical definitions are given below :—

(1) A point has position but is said to have no magnitude, *i.e.*, no length or breadth.

(2) A line has length but is said to have no breadth.

(3) A surface has length and breadth but no thickness.

(4) A solid has length, breadth and thickness.

(5) Angle :—When two straight lines meet at a point, they are said to form an angle. The straight lines are called the arms of the angle and the point at which they meet, is its vertex.

(6) Right-angle :—

(*a*) When one straight line stands on another so as to make the adjacent angles equal to one another, each of the angles is called a right angle.

(*b*) All right angles are equal. A right angle is divided into 90 equal parts called degrees, each degree is divided into 60 equal parts called minutes, each minute is divided into 60 equal parts called seconds.

(7) Acute-angle :—

An angle which is less than one right angle, is said to be acute, *i.e.*, an acute angle is less than 90 degrees.

(8) Obtuse angle :—

An angle which is greater than one right angle but less than two right angles, is said to be obtuse, *i.e.*, an obtuse angle lies between 90 and 180 degrees.

(9) Straight angle :—

A straight angle is equal to two right angles or 180 degrees.

(10) Reflex angle :—

An angle which is greater than two right angles but less than four right angles, is said to be reflex, *i.e.*, a reflex angle lies between 180 and 360 degrees.

(11) Circle :—

A circle is a plane figure contained by a line traced out by a point which moves so that its distance from a certain fixed point, is always the same. The fixed point is called the centre and the bounding line is called the circumference.

(12) Radius :—

A radius of a circle is a straight line drawn from the centre to the circumference.

It therefore follows that all radii of a circle are equal.

(13) Diameter :—

A diameter of a circle is a straight line drawn through the centre and terminated both ways by the circumference.

(14) Arc of a circle :—

An arc of a circle is any part of the circumference.

(15) Semi-circle :—

A semi-circle is the figure bounded by a diameter of a circle and the part of the circumference cut off by the diameter.

(16) Chord :—

A chord of a circle is a straight line joining any two points on the circumference.

(17) Triangle :—

A triangle is a plane figure bounded by three straight lines.

A triangle is said to be :—

(*a*) right-angled when one of its angles is a right angle.

(*b*) obtuse-angled when one of its angles is obtuse.

(*c*) acute-angled when all three of its angles are acute.

(18) Quadrilateral :—

A quadrilateral is a plane figure bounded by four straight lines.

(19) Parallelogram :—

A parallelogram is a quadrilateral whose opposite sides are parallel.

(20) Rectangle :—

A rectangle is a parallelogram having all the angles right angles.

(21) Square :—

A square is a rectangle having all equal sides and all its angles right angles.

(22) Rhombus :—

A rhombus is a quadrilateral which has all its sides equal, but its angles are not right angles.

(23) Trapezium :—

A trapezium is a quadrilateral which has one pair of parallel sides.

(24) Parallel straight lines :—

Parallel straight lines are such as being in the same plane do not meet however far they are produced beyond both ends.

(25) Area :—

The area of a figure is the quantity or amount of surface contained within its bounding lines.

41. Useful Rules on Mensuration.

(1) Versine, cord and radius of curve :—

To find the versine, half cord or cord and the radius of a curve when any two of the three are known :—

Let us assume that our

V or versine = $5\frac{1}{2}$ feet.
C or cord = 176 feet.
R or radius = 704 feet.

(*a*) **Formula No. 1 :—**

$$\frac{(\frac{1}{2}\text{ cord}^2)}{2\text{ R}} = \text{Versine} = \frac{88 \times 88}{2 \times 704} = \text{V} = 5\tfrac{1}{2}\text{ feet.}$$

conversely $\sqrt{2\text{ R} \times \text{V}}$ $\cdot$ $\frac{1}{2}$ cord $= \sqrt{2 \times 704 \times 5\frac{1}{2}}$
$= \frac{1}{2}$ cord 88 feet.

again $\frac{(\frac{1}{2}\text{ cord}^2)}{\text{V}} = 2\text{ R} \div 2 = \text{R} = \frac{88 \times 88}{5\frac{1}{2}} \div 2 =$
R 704 feet.

(*b*) **Formula No. 2 :—**

$$\frac{(1\frac{1}{2}\text{ cord}^2)}{\text{R}} = \text{V in inches} = \frac{1\frac{1}{2} \times 176 \times 176}{704}$$

$= \text{V}$ 66 inches.

conversely $\sqrt{\frac{\text{R} \times \text{V}}{1\frac{1}{2}}} = \text{cord} = \sqrt{\frac{704 \times 66}{1\frac{1}{2}}} =$
cord 176 feet.

again $\frac{1\frac{1}{2}(\text{cord}^2)}{\text{V}} = \text{R} = \frac{1\frac{1}{2} \times 176 \times 176}{66} =$
R 704 feet.

(*c*) **Formula No. 3:—**

$$\frac{3\ C^2}{2\ R} = V \text{ in inches} = \frac{3 \times 176 \times 176}{2 \times 704} = V\ 66$$

inches.

conversely $\sqrt{\frac{2\ R \times V}{3}} = \text{cord} = \sqrt{\frac{2 \times 704 \times 66}{3}}$

$= \text{cord } 176$ feet.

again $\frac{3\ C^2}{V} = 2\ R \div 2 = R = \frac{3 \times 176 \times 176}{66}$

$\div\ 2 = R\ 704$ feet.

(*d*) **Formula No. 4:—**

$$\frac{C^2}{8R} = V = \frac{176 \times 176}{8 \times 704} = V\ 5\tfrac{1}{2} \text{ feet.}$$

conversely $\sqrt{8\ R \times V} = \text{cord} = \sqrt{8 \times 704 \times 5\tfrac{1}{2}}$

$= \text{cord } 176$ feet.

again $\frac{C^2}{V} = 8\ R \div 8 = R = \frac{176 \times 176}{5\frac{1}{2}} \div 8$

$= R\ 704$ feet.

In the four cases explained above, the versine, cord and radius are found out from each formula using it conversely.

(*e*) To find versine.

Divide 396 by radius in chains (of 66 feet). The quotient will be versine in inches.

Example :—R=22 chains.

$\therefore\ 396 \div 22 = 18$ inches versine.

(*f*) To find Radius.

Divide 396 by versine in inches. The quotient will be radius in chains of 66 feet.

$\therefore 396 \div 18 = 22$ chains radius.

(2) Degree of curve :—

(*a*) The curvature of a curve is described by stating the number of degrees in the angle subtended at the centre by an arc of 100 feet in length, which angle is called the "angle of deflection." Its value is :—

$$\text{Angle of deflection in degrees} = \frac{5730}{\text{Radius in feet.}}$$

A curve is called a "one degree curve," a "two degree curve" and so on according to its angle of deflection. Hence :—

A "one degree curve" means a curve of 5730 feet radius.

A "two degree curve" means a curve of 2865 feet radius.

A "three degree curve" means a curve of 1910 feet radius and so on.

(*b*) To find the radius of any curve when the degree is known :—

Divide $57 \cdot 3 \times 100$ by the degree. The quotient will be equal to the radius in feet.

If the degree of curve is 2, we have.

$$\frac{57 \cdot 3 \times 100}{2} = 2865 \text{ radius.}$$

(c) To find the degree of curvature of any curve by measurement :—

Stretch a cord 214 feet in length on the inside of a curve and measure the versine at the centre, *i.e.*, at 107 feet. Each foot of the versine is equal to a degree and each inch of it is equal to 5 minutes of curvature.

The degree of curvature of any curve is therefore equal to $\frac{\frac{1}{2} C^2}{2 R}$ where the cord is 214 feet in length.

Example :—The radii of curves are 5730, 3820 and 2865 feet respectively. Find out the degrees of curve in all three cases.

Formula $\frac{\frac{1}{2} C^2}{2 R}$ = degree.

We therefore have :—

(1) $\frac{107 \times 107}{2 \times 5730} = \frac{11449}{11460} = 1$ degree curve.

(2) $\frac{107 \times 107}{2 \times 3820} = \frac{11449}{7640} = 1^\circ\text{-}30' = 1\frac{1}{2}^\circ$ curve.

(3) $\frac{107 \times 107}{2 \times 2865} = \frac{11449}{5730} \doteq 2$ degree curve.

We can now find out the degree of curvature of any curve by the above formula. In the following table, the degrees of curvature worked out from their radii in feet according to the above formula are shown.

Table of degrees. Formula $\frac{\frac{1}{2} c^2}{2 R}$ = degrees where C is = 214 feet.

Radius in feet.	$\frac{\frac{1}{2} C^2}{2 R}$ = Degree.		Angle of deflection in Degrees. Degrees.	Mts.
		°	°	′
11459	$\frac{107 \times 107}{2 \times 11459}$ =	$\frac{1}{2}$	0	30
5730	$\frac{107 \times 107}{2 \times 5730}$ =	1	1	00
3820	$\frac{107 \times 107}{2 \times 3820}$ =	$1\frac{1}{2}$	1	30
2865	$\frac{107 \times 107}{2 \times 2865}$ =	2	2	00
2292	$\frac{107 \times 107}{2 \times 2292}$ =	$2\frac{1}{2}$	2	30
1910	$\frac{107 \times 107}{2 \times 1910}$ =	3	3	00
1637	$\frac{107 \times 107}{2 \times 1637}$ =	$3\frac{1}{2}$	3	30
1433	$\frac{107 \times 107}{2 \times 1433}$ =	4	4	00

Table of degrees. Formula $\frac{\frac{1}{2} c^2}{2 R}$ = degrees where C is = 214 feet.—(Contd.)

Radius in feet.	$\frac{\frac{1}{2} C^2}{2 R}$ = Degrees.		Angle of deflection in Degrees.	
			Degrees.	Mts.
		°	°	′
1273	$\frac{107 \times 107}{2 \times 1273}$ =	$4\frac{1}{2}$	4	30
1146	$\frac{107 \times 107}{2 \times 1146}$ =	5	5	00
955	$\frac{107 \times 107}{2 \times 955}$ =	6	6	00
819	$\frac{107 \times 107}{2 \times 819}$ =	7	7	00
717	$\frac{107 \times 107}{2 \times 717}$ =	8	8	00
637	$\frac{.107 \times 107}{2 \times 637}$ =	9	9	00
573 and so on.	$\frac{107 \times 107}{2 \times 573}$ =	10	10	00

(*d*) To find the degree of a curve :—

Measure the versine of any curve with a cord 61′-9½″ long. As many inches is the versine, so many are the degrees of the curvature of the curve since each inch of the versine represents 1 degree of the curve.

(*e*) To find the degree of a curve :—

The versine in inches of a

20	feet cord	÷ 0·10
30	"	÷ 0·23
40	"	÷ 0·41
44	"	÷ 0·50
50	"	÷ 0·65
60	"	÷ 0·94
80	"	÷ 1·67
100	"	÷ 2·61

will give the number of degrees of the curve.

(3) To find the angle of a crossing when the lead or number is known :—

$\frac{57 \cdot 3}{N}$ = Angle. Divide 57·3 by the number of the crossing. The quotient will be the angle in degrees and decimals of a degree. To bring decimals of a degree to minutes, multiply by 60 and divide by 100.

Example :—

The numbers of our crossings are 1 in 8, 10 and 12. Find out their angles.

$57 \cdot 3 \div 8 = 7 \cdot 1625^\circ$ angle of 1 in 8 crossing.
$57 \cdot 3 \div 10 = 5 \cdot 73^\circ$ angle of 1 in 10 crossing.
$57 \cdot 3 \div 12 = 4 \cdot 775^\circ$ angle of 1 in 12 crossing.

(4) To find the number of a crossing when the angle is known :—

$$\frac{57 \cdot 3}{\text{angle}} = \text{Number of crossing.}$$

Divide 57·3 by the angle of crossing. The quotient will be the number or lead of the crossing.

Example :—

The angles of our crossings are $7 \cdot 1625^\circ$, $5 \cdot 73^\circ$ and $4 \cdot 775^\circ$. Find out their numbers.

$57 \cdot 3 \quad 7 \cdot 1625^\circ = 8 = 1$ in 8 crossing.
$57 \cdot 3 \quad 5 \cdot 73^\circ = 10 = 1$ in 10 crossing.
$57 \cdot 3 \div 4 \cdot 775^\circ = 12 = 1$ in 12 crossing.

(5) Properties of the Circle :—

$\text{Diameter} \times 3 \cdot 14159 = \text{Circumference.}$
$\text{Diameter}^2 \times 0 \cdot 7854 = \text{Area of circle.}$
$\text{Radius} \times 6 \cdot 28318 = \text{Circumference.}$
$\text{Circumference} \times 0 \cdot 31831 = \text{Diameter.}$
$3 \cdot 5449 \times \sqrt{\text{area of circle}} = \text{Circumference.}$
$1 \cdot 1283 \times \sqrt{\text{area of circle}} = \text{Diameter.}$

(6) To find the area of a circle or well :—

(*a*) $\frac{22}{7} \times \text{Diameter}^2$ = area of a circle or well

(*b*) Multiply the square of the radius (which means $\frac{\text{Diameter}^2}{4}$) by $\frac{22}{7}$. The product will be the area of the circle.

(7) To find the circumference of a circle, the diameter being given :—
Multiply the diameter by $\frac{22}{7}$. The product will be the circumference.

(8) To find the diameter of a circle, the circumference being given :—
Divide the circumference by $\frac{22}{7}$. The quotient will be the diameter.

(9) To find the diameter of a circle, the area being given :—
Divide the area by $\frac{22}{7}$ and extract the square root of the quotient. The root will be the radius of the circle and therefore twice the root will be the diameter.

(10) Properties of a right-angled triangle :—

(1) Sine $= \frac{\text{Perpendicular}}{\text{Hypotenuse}}$;

(2) Co-sine $\frac{\quad}{\text{Hypotenuse}}$,

(3) Secant $= \dfrac{\text{Hypotenuse}}{\text{Base}}$;

(4) Co-secant $= \dfrac{\text{Hypotenuse}}{\text{Perpendicular}}$;

(5) Tangent $= \dfrac{\text{Perpendicular}}{\text{Base}}$;

(6) Co-tangent $= \dfrac{\text{Base}}{\text{Perpendicular}}$;

(7) Versed sine $= \dfrac{\text{Hypotenuse} - \text{Base}}{\text{Hypotenuse}}$;

(8) Co-versed sine =

$$\frac{\text{Hypotenuse} - \text{Perpendicular}}{\text{Hypotenuse}};$$

(9) Hypotenuse =

$$\sqrt{\text{Base}^2 + \text{Perpendicular}^2}$$

(10) Base =

$$\sqrt{\text{Hypotenuse}^2 - \text{Perpendicular}^2};$$

(11) Perpendicular =

$$\sqrt{\text{Hypotenuse}^2 - \text{Base}^2}.$$

(11) A right angle can be easily laid on the ground by the use of the following table which gives the base, perpendicular and the hypotenuse. The base must coincide with the given line.

Base.	Perpendicular.	Hypotenuse.
4	3	5
12	5	13
24	7	25
40	9	41
60	11	61
84	13	85
96	28	100

(12) The two sides of a right-angled triangle being given, to find the hypotenuse.

'Add the squares of the two sides and extract the square root of the sum; the square root will be the hypotenuse.'

(13) The hypotenuse and one side of a right-angled triangle being given, to find the other side.

'From the square of the hypotenuse, subtract the square of the given side and extract the square root of the remainder, this square root will be the required side.'

(14) To find the area of a triangle :—

(*a*) Multiply the base of the triangle by its altitude and divide the product by 2.

The quotient will be the area of the triangle.

(*b*) If the three sides of the triangle are given, its area can be found by using the following formula :—

$\sqrt{S(S-A)(S-B)(S-C)}$ = Area of triangle where A, B, C are the three sides of the triangle and S is half their sum.

(15) To find the area of a rectangle :—

'Multiply any two adjacent sides of a rectangle. The product will be the required area.'

(16) To find the volume of a cylinder :—

'Multiply the area of the base by the height. The product will be the required volume.'.

(17) To find the contents of a barrel :—

(if the diameter of the barrel is equal for the whole length)

'Multiply the square of the diameter in inches by the depth in inches and divide the product by 359. The result will be the contents of the barrel in cubic feet.'

(18) To find the contents of a barrel :—

(if the diameter at the centre is larger than at the ends)

'Square the diameter of the centre in inches and multiply it by 2. Add to this the square of the end diameter. Then multiply

the product by the length of the barrel and divide by 1077.'

(19) To find the cubical contents of a round timber log :—

'¼ Girth squared × length = Cubic feet.'

If the log is irregular or tapers much, take the girth at both ends and the centre and divide it by 3, *i.e.*, take the mean girth. The girth is to be taken exclusive of the bark of the tree but if the bark is on, a deduction of 0·1 of the girth for thick barked trees and of 0·08 for thin barked trees should be made when measuring the girth. This is an approximate rule. A better way is to multiply the square of 0·2 of the girth by double the length and the product will be the cubical contents.

(20) To find the quantity of earth excavated from wells in cft.

(*a*) Square the diameter and multiply the result by 0·7854 and by the depth in feet; the result will be the quantity excavated in cubic feet.

(*b*) $\frac{22}{7} \times \frac{\text{Diameter}^2}{4} \times \text{Depth} = \text{Cubic contents.}$

(21) Water :—

224 gallons	= 35·84 cft.	= 2240 lbs.	=1 ton.
11·2 do.	= 1·8 cft.	= 112 lbs.	=1 cwt.
6·25 do.	= 1 cft.	= 62½ lbs.	
1 do.	= 0·16 cft.	= 10 lbs.	
Cubic feet	× 35·84	= Tons.	
Cubic feet	× 1·8	= Cwt.	
Cubic feet	× 6·25	= Gallons.	

(22) Rainfall :—

Inches of rainfall	× 2323200	= Cft. per square mile.
Inches of rainfall	× 14½	= Millions of gallons per square mile.

(23) To find approximate quantity of water in wells :—

Square the diameter in inches and cut off the right hand figure as a decimal ; the result will be gallons in each 3 feet of depth of the well.

(24) To find the contents of a round tank in gallons :—

Square the diameter in inches and multiply by the depth in inches and divide the result by 353. The quotient will be equal to the number of gallons.

(25) To find the contents of a square tank in gallons :—

Multiply the length, breadth and depth together in feet and the result by 6·25. The product will be the number of gallons.

(26) To find the weight of rails in tons per mile of single track :—

(*a*) Multiply the weight of rail per yard by 1·571. The product will be the weight of rails required for one mile of single track.

(*b*) Multiply the weight per yard by 11 and divide the result by 7. The quotient will be the quantity of rails in tons approximately.

(27) To find the sectional area of rails in inches :—

Divide the weight of rail in lbs. per yard by 10·08. The quotient will be the sectional area in inches.

(28) To find the weight of rails in lbs. per yard :—

Multiply the sectional area of rail in inches by 10·08. The product will be the weight of rail in lbs. per yard.

(29) To find the radius of an arc, rise and span being given :—

Square half the cord and to this add the square of the rise and divide the product by twice the rise. The quotient will be the required radius.

(30) Quantity of ballast required for one mile of track :—

Line.	Width of ballast at top in feet.	Ballast per Lineal foot. cft.	Ballast per mile cft.
Single ..	11	19·274	101766
Double ..	25	39·813	210212

(31) Decimal Equivalents of a Foot:—

In.	0	1/16	1/8	3/16	1/4	5/16	3/8	16	1/2
0	0·0000	0·0052	0 0104	0·0156	0·0208	0·0260	0·0313	0·0365	0·0417
1	0·0833	0·0885	0·0937	0·0990	0·1042	0·1094	0·1146	0·1198	0·1250
2	0·1667	0·1719	0·1771	0·1823	0·1875	0·1927	0·1979	0·2031	0·2083
3	0·2500	0·2552	0·2604	0·2656	0·2708	0·2760	0·2813	0·2865	0·2917
4	0·3333	0·3385	0·3437	0·3490	0·3542	0·3594	0·3646	0·3698	0·3750
5	0 4167	0·4219	0·4271	0·4323	0·4375	0·4427	0·4479	0·4531	0·4583
6	0·5000	0·5052	0·5104	0·5156	0·5208	0·5260	0·5313	0·5365	0·5417
7	0·5833	0·6885	0·5937	0·5990	0·6042	0·6094	0·6146	0·6198	0·6250
8	0·6667	0·6719	0·6771	0·6823	0·6875	0·6927	0·6979	0·7031	0·7083
9	0·7500	0·7552	0·7604	0·7656	0·7708	0·7760	0·7813	0·7865	0·7917
10	0·8333	0·8385	0·8437	0·8490	0·8542	0·8594	0·8646	0·8698	0 8750
11	0·9167	0·9219	0·9271	0·9323	0·9375	0·9427	0·9479	0·9531	0·9583

DECIMAL EQUIVALENTS OF A FOOT.—*contd.*

In.	0	$\frac{9}{16}$	$\frac{5}{8}$	$\frac{11}{16}$	$\frac{3}{4}$	$\frac{13}{16}$	$\frac{7}{8}$	$\frac{15}{16}$
0	0·0000	0·0469	0·0521	0·0573	0·0625	0·0677	0·0729	0·0781
1	0·0833	0·1302	0·1354	0·1406	0·1458	0·1510	0·1563	0·1615
2	0·1667	0·2135	0·2188	0·2240	0·2292	0·2344	0·2396	0·2448
3	0·2500	0·2969	0·3021	0·3073	0·3125	0·3177	0·3229	0·3281
4	0·3333	0·3802	0·3854	0·3906	0·3958	0·4010	0·4063	0·4115
5	0·4167	0·4635	0·4688	0·4740	0·4792	0·4844	0·4896	0·4948
6	0·5000	0·5469	0·5521	0·5573	0·5625	0·5677	0·5729	0·5781
7	0·5833	0·6302	0·6354	0·6406	0·6458	0·6510	0·6563	0·6615
8	0·6667	0·7135	0·7187	0·7240	0·7292	0·7344	0·7396	0·7448
9	0·7500	0·7969	0·8021	0·8073	0·8125	0·8177	0·8229	0·8281
10	0·8333	0·8802	0·8854	0·8906	0·8958	0·9010	0·9063	0·9115
11	0·9167	0·9635	0·9688	0·9740	0·9792	0·9844	0·9896	0·9948

(32) Squares, Cubes, Square Roots, and Cube roots.

No.	Square.	Cube.	Square Root.	Cube Root.
1	1	1	1·0	1·0
2	4	8	1·41421	1·2599
3	9	27	1·73205	1·4422
4	16	64	2·0	1·5874
5	25	125	2·23607	1·7100
6	36	216	2·44949	1·8171
7	49	343	2·64575	1·9129
8	64	512	2·82843	2·0
9	81	729	3·0	2·0801
10	100	1000	3·16228	2·1544
11	121	1331	3·31662	2·2240
12	144	1728	3·46410	2·2894
13	169	2197	3·60555	2·3513
14	196	2744	3·74166	2·4101
15	225	3375	3·87298	2·4662
16	256	4096	4·0	2·5198
17	289	4913	4·12311	2·5713
18	324	5832	4·24264	2·6207
19	361	6859	4·35890	2·6684
20	400	8000	4·47214	2·7144
21	441	9261	4·58258	2·7589
22	484	10648	4·69042	2·8020

Squares, Cubes, Square Roots, and Cube roots—*contd.*

No.	Square.	Cube.	Square Root.	Cube Root.
23	529	12167	4·79583	2·8439
24	576	13824	4·89898	2·8845
25	625	15625	5·0	2·9240
26	676	17576	5·09902	2·9625
27	729	19683	5·19615	3·0
28	784	21952	5·29150	3·0366
29	841	24389	5·38516	3·0723
30	900	27000	5·47723	3·1072
31	961	29791	5·56776	3·1414
32	1024	32768	5·65685	3·1748
33	1089	35937	5·74456	3·2075
34	1156	39304	5·83095	3·2396
35	1225	42875	5·91608	3·2711
36	1296	46656	6·0	3·3019
37	1369	50653	6·08276	3·3322
38	1444	54872	6·16441	3·3620
39	1521	59319	6·245	3·3912
40	1600	64000	6·32456	3·4200
41	1681	68921	6·40312	3·4482
42	1764	74088	6·48074	3·4760
43	1849	79507	6·55744	3·5034
44	1936	85184	6·63325	3·5303

Squares, Cubes, Square Roots, and Cube roots—*contd.*

No.	Square.	Cube.	Square Root.	Cube Root.
45	2025	91125	6·70820	3·5560
46	2116	97336	6·78233	3·5830
47	2209	103823	6·85565	3·6088
48	2304	110592	6·92820	3·6342
49	2401	117649	7·0	3·6593
50	2500	125000	7·07107	3·6840
51	2601	132651	7·14143	3·7084
52	2704	140608	7·21110	3·7325
53	2809	148877	7·28011	3·7563
54	2916	157464	7·34847	3·7798
55	3025	166375	7·4162	3·8030
56	3136	175616	7·48331	3·8259
57	3249	185193	7·54983	3·8485
58	3364	195112	7·61577	3·8709
59	3481	205379	7·68115	3·8930
60	3600	216000	7·74597	3·9149
61	3721	226981	7·81025	3·9365
62	3844	238328	7·87401	3·9579
63	3969	250047	7·93725	3·9791
64	4096	262144	8·0	4·0
65	4225	274625	8·06226	4·0207
66	4356	287496	8·12404	4·0412

Squares, Cubes, Square Roots, and Cube roots—*contd.*

No.	Square.	Cube.	Square Root.	Cube Root.
67	4489	300763	8·18535	4·0615
68	4624	314432	8·24621	4·0817
69	4761	328509	8·30662	4·1016
70	4900	343000	8·36660	4·1213
71	5041	357911	8·42615	4·1408
72	5184	373248	8·48528	4·1602
73	5329	389017	8·54400	4·1793
74	5476	405224	8·60233	4·1983
75	5625	421875	8·66025	4·2172
76	5776	438976	8·71780	4·2358
77	5929	456533	8·77496	4·2543
78	6084	474552	8·83176	4·2727
79	6241	493039	8·88819	4·2908
80	6400	512000	8·94427	4·3089
81	6561	531441	9·0	4·3267
82	6724	551368	9·05539	4·3445
83	6889	571787	9·11043	4·3621
84	7056	592704	9·16515	4·3795
85	7225	614125	9·21954	4·3968
86	7396	636056	9·27362	4·4140
87	7569	658503	9·32738	4·4310
88	7744	681472	9·38083	4·4480

Squares, Cubes, Square Roots, and Cube roots—*contd.*

No.	Square.	Cube.	Square Root.	Cube Root.
89	7921	704969	9·43398	4·4647
90	8100	729000	9·48683	4·4814
91	8281	753571	9·53939	4·4979
92	8464	778688	9·59166	4·5144
93	8649	804357	9·64365	4·5307
94	8836	830584	9·69536	4·5468
95	9025	857375	9·74679	4·5629
96	9216	884736	9·79796	4·5789
97	9409	912673	9·84886	4·5947
98	9604	941192	9·89949	4·6104
99	9801	970299	9·94987	4·6261
100	10000	1000000	10·0	4·6416
101	10201	1030301	10·04988	4·6570
102	10404	1061208	10·09950	4·6723
103	10609	1092727	10·14889	4·6875
104	10816	1124864	10·19804	4·7027
105	11025	1157625	10·24695	4·7177
106	11236	1191016	10·29563	4·7326
107	11449	1225043	10·34408	4·7475
108	11664	1259712	10·39230	4·7622
109	11881	1295029	10·44031	4·7769
110	12100	1331000	10·48809	4·7914

Squares, Cubes, Square Roots, and Cube Roots—*contd.*

No.	Square.	Cube.	Square Root.	Cube Root.
111	12321	1367631	10·53565	4·8059
112	12544	1404928	10·58301	4·8203
113	12769	1442897	10·63015	4·8346
114	12996	1481544	10·67708	4·8488
115	13225	1520875	10 72381	4·8629
116	13456	1560896	10·77033	4·877
117	13689	1601613	10·81665	4·8910
118	13924	1643032	10·86278	4·9049
119	14161	1685159	10·90871	4·9187
120	14400	1728000	10·95445	4·9324
121	14641	1771561	11·0	4·9461
122	14884	1815848	11·04536	4·9597
123	15129	1860867	11·09054	4·9732
124	15376	1906624	11·13553	4·9866
125	15625	1953125	11·18034	5·0
126	15876	2000376	11·22497	5·0133
127	16129	2048383	11·26943	5·0265
128	16384	2097152	11·31371	5·0397
129	16641	2146689	11·35782	5·0528
130	16900	2197000	11·40188	5·0652
131	17161	2248091	11·44552	5·0788
132	17424	2299968	11·48913	5·0916

Squares, Cubes, Square Roots, and Cube Roots—*contd.*

No.	Square.	Cube.	Square Root.	Cube Root.
133	17689	2352637	11·53256	5·1045
134	17956	2406104	11·57584	5·1172
135	18225	2460375	11·61895	5·1299
136	18496	2515456	11·6619	5·1426
137	18769	2571353	11·70470	5·1551
138	19044	2628072	11·74734	5·1676
139	19321	2685619	11·78983	5·1801
140	19600	2744000	11·8322	5·1925
141	19881	2803221	11·87434	5·2048
142	20164	2863288	11·9164	5·2171
143	20449	2924207	11·9583	5·2293
144	20736	2985984	12·0	5·2415
145	21025	3048625	12·0416	5·2536
146	21316	3112136	12·08305	5·2656
147	21609	3176523	12·12436	5·2776
148	21904	3241792	12·16553	5·2896
149	22201	3307949	12·20656	5·3015
150	22500	3375000	12·24745	5·3133
151	22801	3442951	12·28821	5·3251
152	23104	3511808	12·32883	5·3368
153	23409	3581577	12·36932	5·3485
154	23716	3652264	12·40967	5·3601

Squares, Cubes, Square Roots, and Cube Roots—*contd.*

No.	Square.	Cube.	Square Root.	Cube Root.
155	24025	3723875	12·44990	5·3717
156	24336	3796416	12·49000	5·3832
157	24649	3869893	12·52996	5·3947
158	24964	3944312	12·56981	5·4061
159	25281	4019679	12·60952	5·4175
160	25600	4096000	12·64911	5·4288
161	25921	4173281	12·68858	5·4401
162	26244	4251528	12·72792	5·4514
163	26569	4330747	12·76715	5·4626
164	26896	4410944	12·80625	5·4737
165	27225	4492125	12·84523	5·4848
166	27556	4574296	12·88410	5·4950
167	27889	4657463	12·92285	5·5069
168	28224	4741632	12·96148	5·5178
169	28561	4826809	13·00000	5·5288
170	28900	4913000	13·03840	5·5397
171	29241	5000211	13·07670	5·5505
172	29584	5088448	13·11488	5·5613
173	29929	5177717	13·15295	5·5721
174	30276	5268024	13·19091	5·5828
175	30625	5359375	13·22876	5·5934
176	30376	5451776	13·26650	5·6041

SQUARES, CUBES, SQUARE ROOTS, AND CUBE ROOTS—*contd.*

No.	Square.	Cube.	Square Root.	Cube Root.
177	31329	5545233	13·30413	5·6147
178	31684	5639752	13·34166	5·6252
179	32041	5735339	13·37909	5·6357
180	32400	5832000	13·41641	5·6462
181	32761	5929741	13·45362	5·6567
182	33124	6028568	13·49074	5·6671
183	33489	6128487	13·52775	5·6774
184	33856	6229504	13·56466	5·6877
185	34225	6331625	13·60147	5·6980
186	34596	6434856	13·63818	5·7083
187	34969	6539203	13·67479	5·7185
188	35344	6644672	13·71131	5·7287
189	35721	6751269	13·74773	5·7388
190	36100	6859000	13·78405	5·7489
191	36481	6967871	13·82028	5·7590
192	36864	7077888	13·85641	5·7689
193	37249	7189057	13·89244	5·7790
194	37636	7301384	13·92839	5·7890
195	38025	7414875	13·96424	5.7988
196	38416	7529536	14·000	5·8088
197	38809	7645373	14·03567	5·8186
198	39204	7762392	14·07125	5·8285
199	39601	7880599	14·10674	5·8383
200	40000	8000000	14·14214	5·8480

42. Miscellaneous Weights & Measures.

(1) Sundry measures.

16	Ounces	=	1 Pound.
14	Pounds	=	1 Stone.
2	Stones or 28 Pounds	=	1 Quarter.
4	Quarters	=	1 Hundred-weight.
20	Hundred-weights	=	1 Ton.
1	Dozen	=	12
1	Score	=	20
1	Gross	=	12 Dozen or 144.
24	Sheets	=	1 Quire.
20	Quires	=	1 Ream.

(2) Weight of metals and alloys.

Description.	Weight of 1 Cft. in pounds.
Aluminium	166·6
Copper sheet	549·0
Copper wire	555·0
Gold	1204·0
Silver	653·8
Cast iron	450·0
Wrought iron	480·0
Steel	490·0
Zinc cast	428·0
Tin cast	455·0
Lead sheet	710·0
Brass sheet	525·0
White metal	456·32

(3) Weight of miscellaneous substances.

Description.	Weight of 1 Cft. in pounds.
Cement Portland	86 to 94
Clay	125
Coal	79 to 95
Coke	46
Earth	100 to 125
Ivory	114
Lime	53
Mortar	86 to 118
Sand wet	130
Pitch	70
Tallow	59
Chalk	110
Trap stone	170
Teak wood	46 to 54

(4) Weight of miscellaneous materials.

Description.	Weight in lbs. per cubic foot.
Black cotton soil dry	70
Do. do. do. wet	125
Yellow soil, dry	65
Trap stone	175
Lime stone	170
Sand stone	140 to 155
Coal ashes, loose, dry	50
Sand	100
Ashlar & block in course	$\frac{1}{13}$ ton
Coursed rubble masonry 1st sort	$\frac{1}{14}$ ton
Do. do. do. 2nd & 3rd sort	$\frac{1}{16}$ ton
Cement concrete (stone), 1 : 2 : 4	$\frac{1}{16}$ ton
Lime concrete (stone) 1 : 2 : 4	$\frac{1}{17}$ ton
Brick masonry	$\frac{1}{20}$ ton

(5) WEIGHT OF ROOFS :—

Description.	Weight.
Corrugated iron sheeting 18 S. W. G. including overlap	300 lbs. per 100 sft. of roof
Corrugated iron sheeting 20 S. W. G. including overlap	240 ,, ,, ,,
Galvanized iron 24 S. W. G. on 1″ boarding	500 ,, ,, ,,
Mangalore tiles excluding battens	1000 ,, ,, ,,
Country tiles half round excluding battens. Single tiling	1400 ,, ,, ,,
Country tiles half round excluding battens. Double tiling	2400 ,, ,, ,,
Thatch including frames 6″ thick	650 ,, ,, ,,
Do. do. do. 9″ do	1000 ,, ,, ,,
Reinforced cement concrete (stone) slab 6″ thick .	7500 ,, ,, ,,
Pine ceiling boards ½″ thick	150 lbs. per 100 sft. of material
Do. do. do. ¾″ thick	230 ,, ,, ,,
Teak ceiling do. ¾″ thick	300 ,, ,, ,,

(6) Roof tiles :—

Description.	No. per 100 sft. of roof.	No. per ton.	Spacing of battens centre to centre.
Mangalore flat	150	400	12½″
Do. ridge	75	300	..
Country tiles half round 7″ long ..	1600	Single tiling	Matting laid on battens.
Country tiles half round 9″ long ..	1350	Do. do.	Do. do.
Country tiles half round 10″ long .	1200	Do. do.	Do. do.
Country tiles half round 11″ long ..	1100	Do. do.	Do. do.
Mangalore flat	5000	= 1 (12½ ton) wagon load.	
Do. do.	250	= 1 cart load.	
Do. ridge	125	= 1 cart load.	
		T. Cwt. Qr. Lb.	
Do. do.	1000	= 3 7 0 0	
Do. flat	1000	= 2 10 0 0	

In carrying tiles by rail, the breakage in transit is less if the wagon is fully loaded.

(7) BRICKS AND BRICK WORK :—

Bricks 9″ × 4½″ × 2½″ in size.

1410 required for 100 cft. plain brickwork.

650 do. do. 100 sft. brick on edge.

375 do. do. 100 sft. brick laid flat.

These figures allow 5% for wastage.

(8) WEIGHT OF LIQUIDS :—

Description.	Weight of 1 cft. in pounds.	Weight of 1 gallon in pounds.
Water	62·50	10·0
Coal tar	63·45	10·2
Pitch	70·00	10·9
Petroleum crude	55·25	8·8
Petroleum refined	60·50	9·68
Turpentine	53·00	8·7
Oil castor	57·50	9·25
,, linseed boiled	58·60	9·4
,, cylinder mineral ..	59·25	9·5
,, Kerosine 125°	50·00	8·12

1 Case kerosine oil = 65 lbs. = 8 gallons.

1 Tin do. do. = 32½ lbs. = 4 gallons.

(9) WEIGHT OF ANGLE IRON :—

Size in inches.	Weight per lineal foot in pounds.
$1\frac{1}{2} \times 1\frac{1}{2} \times \frac{1}{4}$	2·25
$1\frac{3}{4} \times 1\frac{3}{4} \times \frac{5}{16}$	3·25
$2 \times 2 \times \frac{1}{4}$	3·13
$2 \times 2 \times \frac{3}{8}$	4·50
$2\frac{1}{4} \times 2\frac{1}{4} \times \frac{1}{4}$	3·54
$2\frac{1}{4} \times 2\frac{1}{4} \times \frac{5}{16}$	4·36
$2\frac{1}{4} \times 2\frac{1}{4} \times \frac{3}{8}$	5·16
$2\frac{1}{4} \times 2\frac{1}{4} \times \frac{7}{16}$	5·75
$2\frac{1}{2} \times 2\frac{1}{2} \times \frac{1}{4}$	3·96
$2\frac{1}{2} \times 2\frac{1}{2} \times \frac{5}{16}$	4·88
$2\frac{1}{2} \times 2\frac{1}{2} \times \frac{3}{8}$	5·78
$2\frac{1}{2} \times 2\frac{1}{2} \times \frac{1}{2}$	7·50
$3 \times 3 \times \frac{1}{4}$	4·79
$3 \times 3 \times \frac{3}{8}$	7·03
$3 \times 3 \times \frac{7}{16}$	8·11
$3 \times 3 \times \frac{1}{2}$	9·17
$3 \times 3 \times \frac{9}{16}$	10·19
$3 \times 3 \times \frac{5}{8}$	11·20
$3\frac{1}{4} \times 3\frac{1}{4} \times \frac{5}{16}$	6·45
$3\frac{1}{4} \times 3\frac{1}{4} \times \frac{3}{8}$	7·66
$3\frac{1}{4} \times 3\frac{1}{4} \times \frac{7}{16}$	8·84

WEIGHT OF ANGLE IRON :—*contd.*

Size in inches.	Weight per lineal foot in pounds.
$3\frac{1}{4} \times 3\frac{1}{4} \times \frac{1}{2}$	10·00
$3\frac{1}{4} \times 3\frac{1}{4} \times \frac{5}{8}$	12·24
$3\frac{1}{2} \times 3\frac{1}{2} \times \frac{3}{8}$	8·28
$3\frac{1}{2} \times 3\frac{1}{2} \times \frac{7}{16}$	9·57
$3\frac{1}{2} \times 3\frac{1}{2} \times \frac{1}{2}$	10·83
$3\frac{1}{2} \times 3\frac{1}{2} \times \frac{9}{16}$	12·07
$3\frac{1}{2} \times 3\frac{1}{2} \times \frac{5}{8}$	13·28
$3\frac{1}{2} \times 3\frac{1}{2} \times \frac{3}{4}$	15·50
$3\frac{3}{4} \times 3\frac{3}{4} \times \frac{3}{8}$	8·91
$3\frac{3}{4} \times 3\frac{3}{4} \times \frac{7}{16}$	10·30
$3\frac{3}{4} \times 3\frac{3}{4} \times \frac{1}{2}$	11·67
$4 \times 4 \times \frac{3}{8}$	9·53
$4 \times 4 \times \frac{7}{16}$	11·03
$4 \times 4 \times \frac{1}{2}$	12·5
$4 \times 4 \times \frac{9}{16}$	13·94
$4 \times 4 \times \frac{5}{8}$	15·36
$4 \times 4 \times \frac{3}{4}$	18·12
$4 \times 4 \times 1$	25·00
$4\frac{1}{2} \times 4\frac{1}{2} \times \frac{3}{8}$	10·78
$4\frac{1}{2} \times 4\frac{1}{2} \times \frac{1}{2}$	14·17
$4\frac{1}{2} \times 4\frac{1}{2} \times \frac{5}{8}$	17·45
$4\frac{1}{2} \times 4\frac{1}{2} \times \frac{3}{4}$	20·62

(10) Weight of T iron :—

Width and thickness in inches.			Weight per lineal foot in pounds.
$1\frac{1}{4}$	×	$\frac{1}{8}$	1
$1\frac{1}{4}$	×	$\frac{3}{16}$	$1\frac{1}{2}$
$1\frac{1}{4}$	×	$\frac{1}{4}$	2
$1\frac{1}{2}$	×	$\frac{3}{16}$	2
$1\frac{1}{2}$	×	$\frac{1}{4}$	$2\frac{1}{2}$
2	×	$\frac{3}{16}$	$2\frac{1}{2}$
2	×	$\frac{1}{4}$	$3\frac{1}{4}$
$2\frac{1}{2}$	×	$\frac{1}{4}$	4
3	×	$\frac{3}{8}$	7

(U) Weight of wrought iron flat bars:—

Weight per lineal foot of Flat Bar Iron in lbs.

Breadth.

Thickness.	1	1⅛	1¼	1⅜	1½	1⅝	1¾	1⅞	2	2⅛	2¼
¼	·83	·93	1·04	1·14	1·25	1·35	1·46	1·56	1·67	1·77	1·87
5/16	1·04	1·17	1·30	1·43	1·56	1·69	1·82	1·95	2·08	2·21	2·34
⅜	1·25	1·40	1·56	1·72	1·87	2·03	2·19	2·34	2·50	2·66	2·81
7/16	1·46	1·64	1·82	2·0	2·19	2·37	2·55	2·74	2·92	3·10	3·28
½	1·67	1·87	2·08	2·29	2·50	2·71	2·92	3·13	3·34	3·55	3·76
⅝	2·08	2·34	2·60	2·87	3·13	3·39	3·65	3·91	4·17	4·43	4·69
¾	2·50	2·81	3·13	3·44	3·75	4·07	4·38	4·69	5·01	5·32	5·63
⅞	2·92	3·28	3·65	4·01	4·38	4·70	5·11	5·47	5·86	6·21	6·57
1	3·34	3·75	4·17	4·59	5·00	5·43	5·84	6·26	6·68	7·10	7·52

Thickness.	2⅜	2½	2⅝	2¾	2⅞	3	3¼	3½	3¾	4
¼	1·98	2·08	2·19	2·29	2·40	2·50	2·71	2·92	3·13	3·34
5/16	2·47	2·60	2·74	2·87	3·0	3·13	3·39	3·65	3·91	4·17
⅜	2·97	3·13	3·28	3·44	3·60	3·75	4·07	4·38	4·68	5·00
7/16	3·47	3·65	3·83	4·01	4·20	4·38	4·74	5·11	5·47	5·84
½	3·97	4·17	4·38	4·59	4·80	5·01	5·43	5·84	6·26	6·68
⅝	4·95	5·21	5·47	5·74	6·00	6·26	6·78	7·30	7·82	8·35
¾	5·95	6·26	6·57	6·88	7·20	7·51	8·14	8·76	9·39	10·0
⅞	6·94	7·30	7·67	8·03	8·40	8·76	9·49	10·2	10·9	11·6
1	7·93	8·35	8·77	9·18	9·60	10·0	10·8	11·6	12·5	13·3

(12) Weight of round iron :—

Diameter in inches.	Weight per foot in lbs.	Diameter in inches.	Weight per foot in lbs.
$\frac{1}{4}$	0·167	2	10·68
$\frac{3}{8}$	0·376	$2\frac{1}{4}$	13.52
$\frac{1}{2}$	0·668	$2\frac{1}{2}$	16·96
$\frac{5}{8}$	1· 04	$2\frac{3}{4}$	20·19
$\frac{3}{4}$	1· 50	3	24·00
$\frac{7}{8}$	2· 04	$3\frac{1}{4}$	28· 2
1	2· 67	$3\frac{1}{2}$	32· 7
$1\frac{1}{4}$	4· 17	$3\frac{3}{4}$	37· 6
$1\frac{1}{2}$	6· 01	4	42· 8
$1\frac{3}{4}$	8· 18		

Diameter of round iron in inches^2 $\times$ 2·64 = weight in pounds per foot run.

(13) Weight of rolled beams :—

Size in inches.	Weight in lbs. per foot.	Size in inches.	Weight in lbs. per foot.
4 × 2	6	10 × 6	38
$5\frac{3}{4}$ × $2\frac{1}{4}$	8	12 × 5	33
5 × 3	10	12 × 6	42
6 × 3	12	14 × 6	46
7 × $3\frac{1}{2}$	15	15 × 5	52
7 × 4	17	15 × $5\frac{1}{4}$	53
8 × 4	19	15 × $5\frac{7}{8}$	58
9 × 4	22	18 × 7	75
10 × 5	29	20 × $7\frac{1}{2}$	90

(14) **Weight of corrugated iron sheets :—**

Length of sheets in feet.	Weight in lbs. of one sheet.							
	Thickness of gauge.							
	27 inches wide.				32 inches wide.			
	18	20	22	24	18	20	22	24
6	32	25	20	16	33½	30	24	19
7	37½	30	23½	19	44½	36	28	23
8	43	34	26½	21½	51½	40½	32	26
9	48	38	30	24	57½	45½	36	29
10	53½	42½	33½	27	64½	51	40	32½
11	....	....	....	30	....	....	....	....
12	....	....	....	33	....	....	....	....

The average weight of fastenings used for corrugated iron sheet is

G. I. hook bolts 16¼ lbs. per 100 number
,, rivets 2½ lbs. ,, ,, ,,
,, washers 1½ lbs. ,, ,, ,,
,, screws 1½″ 2¼ lbs. ,, ,, ,,

(15) WEIGHT OF NAILS IRON ROSE HEADED :—

Length of nails in inches.	Number of nails in one pound.	Weight of 1000 nails in pounds.
$\frac{7}{8}$	500	2
$1\frac{1}{4}$	250	4
$1\frac{3}{4}$	143	7
2	100	10
$2\frac{1}{2}$	62	16
$2\frac{3}{4}$	50	20
$3\frac{1}{4}$	36	28
$3\frac{3}{4}$	28	36
4	20	50
$4\frac{1}{2}$	15	70

(16) WEIGHT OF NAILS IRON WIRE FRENCH FLAT HEADED FINE :—

Length of nails in inches.	Number of nails in one pound.	Weight of 1000 nails in pounds.
1	800	$1\frac{1}{4}$
$1\frac{1}{4}$	508	2
$1\frac{1}{2}$	300	$3\frac{1}{3}$
2	156	$6\frac{1}{2}$
$2\frac{1}{2}$	78	$12\frac{3}{4}$
3	56	18
4	45	$22\frac{1}{4}$

(17) Weight of wire 100 lineal feet.

B. W. Gauge.	Iron.	Steel.	Brass.	Copper.
0	30·58	30·92	33·43	35·17
1	25·75	26·04	28·15	29·62
2	21·34	21·57	23·32	24·54
3	18·02	18·22	19·70	20·72
4	15·11	15·28	16·52	17·38
5	12·46	12·59	13·62	14·33
6	11·45	11·57	12·51	13·16
7	9·25	9·35	10·11	10·64
8	7·29	7·37	7·97	8·38
9	6·60	6·68	7·22	7·59
10	4·96	5·02	5 43	5·71
11	4·13	4·18	4·52	4·75
12	3·14	3·18	3·43	3·61
13	2·34	2·36	2·55	2·69
14	1·69	1·71	1·85	1·95
15	1·37	1·39	1·50	1·58
16	1·05	1·06	1·15	1·21
17	·80	·81	·87	·92
18	·61	·62	·67	·70
19	·47	·47	·51	·54
20	·32	·33	·34	·37

(18) Painting Memoranda :—

(*a*) One gallon linseed boiled oil weighs 9 lbs. and covers 900 sft. of area on iron.

(*b*) One gallon of linseed boiled oil mixed with 28 lbs. of dry red lead makes 1⅛ gallon of paint which covers 900 sft. of area on iron.

(*c*) One gallon of linseed boiled oil mixed with 7 lbs. of copper red paint makes 1·28 gallons of paint which covers 1,368 sft. of area on iron.

(*d*) One gallon of paint covers approximately :—

225 to 270 sft. of area on stone ;

450 to 630 sft. of area on wood ;

720 to 800 sft. of area on iron.

(*e*) One gallon of tar weighs 10·2 lbs. and covers 108 sft. for the first coat and 144 sft. for the second coat.

(*f*) One barrel of tar holds 25 gallons.

CHAPTER VII.

Standard Dimensions.

43. Standard Dimensions in force 1922.

5 FT. 6 IN. GAUGE.

The "Maximum" and "Minimum" dimensions given in this Schedule are to be observed on all 5 ft. 6 in. gauge railways in India. If, for any reason, it is proposed to execute any work or to procure Bridge Girders, Station Machinery, Rolling Stock or other railway material which will infringe the dimensions or loads given or which will interfere with the elimination of infringements already in existence, the sanction of the Railway Board must be obtained through the Government Inspector of the Railway concerned before such work is commenced or order issued.

Dimensions recommended by the Railway Board are scheduled separately at the end.

I. M.-GENERAL.

Formation, Single Line—

(1) Minimum width in embankment .. .. 16 ft. 6 in.

(2) Minimum width in cutting (excluding side drains) .. .. 16 ft. 6 in.

Formation, Double Line—

(3) Minimum width in embankment .. .. 30 ft. 6 in.

(4) Minimum width in cutting (excluding side drains) .. .. 30 ft. 6 in.

NOTE.—(*a*) On a curve the width of formation for Double Line must be increased by the amount shown in column 9 of the Appendix.

(*b*) Dimensions (1), (2), (3) and (4) will generally be found too small for railways which are ballasted.

Spacing of Tracks—

(5) Minimum distance centre to centre of tracks (outside station limits) .. .. 14 ft. 0 in.

NOTE.—(*a*) The expression "station limits" means the portion of a railway which is under the control of a Station Master and is situated between the outermost signals of the Station, *vide* Rule I (31) Chapter I, Part I, of the General Rules for Open Lines (1906).

(*b*) On a curve the distance between tracks must be increased by the amount shown in column 9 of the Appendix.

Curves—

Maximum degree of curvature on main line—

(6) For unrestricted speed 2° 0′ (radius = 2,865 ft.)

(7) In any circumstances 10° 0′ (radius = 573 ft.)

(*a*) Except between points and crossings the ends of a curve are in practice made easier than the middle; when the ends are properly eased by transition approaches, the radii prescribed in items (6) and (7) may be reduced by the amount of the "shift" which will ordinarily be 2 ft. 8 in.

Gradients in Stations—

(8) Maximum gradient in station yards .. .. 1 in 400

NOTE.—(*a*) For the purpose of the above rule a station yard may be taken to extend—

(*i*) on single line, to a distance of 150 ft. beyond outermost points at either end of the Station.

(*ii*) on double line, from home signal to last stop signal of each line.

(*b*) There must be no change in gradient within 100 ft. of any points or crossings.

(*c*) Hump or gravity yards are exempted from this rule.

Sleepers—

For timber cross sleepers—

(9)	Minimum length	9 ft. 0 in.
(10)	Minimum breadth	10 in.
(11)	Minimum depth	6 in.
(12)	Minimum number of cross sleepers per mile	1906.

NOTE.—(*a*) On bridges where the cross sleepers rest directly on longitudinal girders, the sleepers are to be spaced not more than 2 ft. 6 in. centre to centre, and are to be not less than 6 in. deep exclusive of any notching which may be required to allow for cover plates, camber, etc.

(*b*) The length of cross sleepers laid on longitudinal girders may be reduced to not less than one foot greater than the distance outside to outside of the girder flanges subject to a minimum of 8 ft.

(*c*) When the flooring of a bridge would not give continuous and substantial support throughout the bridge to the wheel of a derailed vehicle up to a distance of 4 ft. from the centre line, substantial transverse timbers, not more than 2 ft. 6 in. apart from centre to centre, should be provided.

Rails—

(13a) Minimum clearance of check rail for a curve	$1\frac{3}{4}$ in.
NOTE.—This clearance must be increased by half the amount of any difference between 5 ft. 6 in. and the gauge to which the curve is actually laid.	
(13b) Minimum clearance of check rails at a level crossing ..	2 in.
(13c) Maximum clearance of check rails at a level crossing ..	$2\frac{1}{4}$ in.
(14) Minimum depth of space for wheel flange from rail level ..	$1\frac{1}{2}$ in.
(15) Minimum weight of rail per yard :—	

Axle load, *i.e.*, weight on a pair of wheels including weight of wheels and axles.	Minimum weight of rail per yard.
12 tons 0 cwt.	60 lbs.
13 ,, 10 ,,	65 ,,
15 ,, 2 ,,	70 ,,
17 ,, 0 ,,	75 ,,
18 ,, 12 ,,	80 ,,
20 ,, 8 ,,	85 ,,
22 ,, 12 ,,	90 ,,
24 ,, 14 ,,	95 ,,
26 ,, 18 ,,	100 ,,

NOTE.—With close spacing of sleepers a less weight per yard is permissible.

(*i*) In respect of wagon axle loads on branch and feeder lines, a less weight per yard may be permitted subject to a suitable speed restriction.

Buildings and Structures—

(16) Minimum horizontal distance, from centre of track to any structure, from rail level to 1 foot above rail level .. .. .. 6 ft. 3 in.

NOTE.—Interlocking gear may project $2\frac{1}{2}$ in. above rail level, see item (20).

(17) Minimum horizontal distance, from centre of track to any structure, except a platform, from 1 foot above rail level to 14 ft. 6 in. above rail level .. 7 ft. 0 in.

NOTE.—(*a*) Under items (16) and (17) any material stacked by the side of the line is to be considered a structure in the sense in which the word is here used. Item (17) also applies to projections of rock, etc., from the side of a cutting.

(*b*) Where the line is on a curve, the horizontal distance of any structure from the centre of adjacent track is to be increased as follows :—

(*i*) where the structure is on the outside of the curve, by the amount shown in column 8 of the Appendix ;

(*ii*) where the structure is on the inside of the curve, by the amount shown in column 4, 5, 6 or 7 of the Appendix, according to the height of the structure above rail level.

(*c*) The clearances given above are absolute minima and are only to be worked to when it is impossible, owing to the structure being between tracks, or for other reasons, to erect it at a greater distance from centre of track. Where possible, structures should always be erected at a greater distance from centre of track than the minimum allowed under the rules.

(18) Minimum height above rail level, for a width of 3 ft. from centre of track, for over-bridges or over-head bracing out of stations .. .. **16 ft. 6 in.**

NOTE.—Where the line is on a curve the width of 3 ft. must be increased by the amount shewn in column 7 or 8 of the Appendix.

(19) Minimum height above rail level for telegraph wires crossing the line .. .. 20 ft. 0 in.

NOTE.—(a). The minimum horizontal distance, from the centre of nearest track, at which a telegraph post may be erected, is the total height of the post *plus* 7 ft. 0 in. Where the line is in cutting, a telegraph post erected on the berm must be at a distance from the edge of the cutting of not less than the total height of the post.

(b) A telegraph post may, with the sanction of the Railway Administration concerned, be erected at a distance of not less than 9 ft. clear from the centre line of the nearest track of railway, provided that it is strongly stayed or tied back on the side away from the railway.

(20) Maximum height above rail level of any part of interlocking or signal gear for a width of 6 ft. 3 in. from centre line of track . **$2\frac{1}{2}$ in.**

NOTE.—Metal ramps must be provided on both sides of all interlocking gear which is fixed between the rails of a track and which projects above rail level, to prevent hanging couplings damaging it.

Tunnels—

(21) Maximum distance apart of refuges in tunnels .. .. 300 ft.

Single Line—

(22) Minimum height above rail level at centre .. .. .. 19 ft. 0 in.

(23) Minimum width at rail level . 13 ft. 0 in.

(24) Minimum width from 1 foot above rail level to 14 ft. 6 in. above rail level .. .. .. 14 ft. 0 in.

(25) Minimum width at 16 ft. 6 in. above rail level .. .. .. 6 ft. 0 in.

NOTE.—Where the line is on a curve, the width of the tunnel must be increased—

(*i*) on the outside of the curve, by the amount shown in column 8 of the Appendix.

(*ii*) on the inside of the curve, by the amount shown in column 4 or 7 of the Appendix.

Double Line—

(26) Minimum height above rail level at centre .. .. .. 20 ft. 0 in.

(27) Minimum width at rail level .. 27 ft. 0 in.

(28) Minimum width from 1 foot above rail level to 14 ft. 6 in. above rail level .. .. .. 28 ft. 0 in.

(29) Minimum width at 16 ft. 6 in. above rail level .. .. .. 20 ft. 0 in.

NOTE.—(*a*) Where the line is on a curve, the width of the tunnel must be increased by the amounts shown in the note to items (23), (24) and (25) above, *plus* the extra allowance between tracks shown in column 9 of the Appendix.

(*b*) Unless the cost is prohibitive, the dimensions given in items (22) to (29) of Chapter I. R. of the Schedule of Recommended Dimensions should be adopted.

II. M.—STATION YARDS.

NOTE.—The expressions "in stations" and "out of stations" are to be interpreted in accordance with the definition of "Station limits" given in Rule I (31), Chapter I, Part I, of the General Rules for Open Lines, 1906, *viz.*—"Station limits" means the portion of a railway which is under the control of a Station Master and is situated between the outermost signals of the Station.

Spacing of Tracks—

(1) Minimum distance centre to centre of tracks .. .. .. 14 ft. 0 in.

NOTE.—(*a*) Where the line is on a curve, the distance must be increased by the amount shown in column 9 of the Appendix.

(*b*) Where it is necessary to place a water column, signal post or overbridge standard, etc., between the tracks, the distance must, if necessary, be increased to comply with items (11), (13) and (14) below and the notes appended thereto.

Length of Sidings—

(2) Minimum clear available length of one siding at any station where it is intended to cross trains—

(*a*) at a non-watering station —7 per cent. longer than the longest train permitted to run on the section.

(*b*) at a watering station—such that when the train engine is standing (and taking water) at the water column the rear of the longest train permitted to run on the section shall be at least 50 ft. clear of the fouling mark.

(*c*) Although, owing to the want of powerful engines, it may not be necessary to provide long sidings in the first instance, land must be acquired for them and no building, level crossing, or other obstruction must be permitted that will interfere with one crossing siding being lengthened to the following dimensions :—

On sections of the Railway where the ruling gradient is—	Minimum clear available length of one siding
1 in 500 or flatter	2,500 feet.

between 1 in 500 and 1 in 300	..	2,000 feet
„ 1 in 300 and 1 in 100		1,800 „
„ 1 in 100 and 1 in 50		1,600 „
steeper than 1 in 50	..	1,200 „

Platforms—

(3) Maximum and minimum horizontal distance from centre of track to face of platform coping.	5 ft. 6 in.
(3a) Minimum horizontal distance from centre of track to face of platform wall	6 ft. 3 in.

NOTE.—(*a*) If the platform be on the inside of a curve, the horizontal distance from centre of track must be increased by the amount laid down in column 4, 5 or 6 of the Appendix according to height of platform.

(*b*) If the platform be on the outside of a curve, the horizontal distance from the centre of track must be increased by the amount laid down in column 8 of the Appendix.

(*c*) Item (3*a*) may be 5 ft. 6 in. instead of 6 ft. 3 in. if the wall is of such a nature that it can be cheaply moved back 9 in. or if the distance from the centre of track alongside a

platform to the next adjoining track or structure be increased by 9 in.

(*d*) Signal wires or supports for signal wires may be allowed underneath the platform coping.

(4) Minimum height above rail level for high passenger platform ..	2 ft. 6 in.
(5) Maximum height above rail level for any passenger platform..	2 ft. 9 in.
(5a) Maximum height above rail level for low passenger platform.	1 ft. 2 in.
(6) Maximum height above rail level for goods, carriage, and horse-loading platform (except end-loading platform)	3 ft. 6 in.

NOTE.—(*a*) Platforms may be flush with rail level.

(*b*) The ends of all platforms (except end-loading platforms) must be ramped to a slope of not less than 1 in 6 for a distance of not less than 3 ft. 6 in. from the edge of the platform, the rest can be either ramped to the same slope or fenced.

Buildings and Structures—

(7) Minimum horizontal distance of any building or longitudinal boundary fence from the edge of

a passenger platform which is not an island platform .. .. 18 ft. 0 in.

Note.—For the return end of platform fencing this item may be reduced to 3 ft. 6 in.

(8) Minimum horizontal distance of any building from the edge of an island passenger platform . .. 12 ft. 0 in.

(9) Minimum horizontal distance of any building from the edge of a goods platform .. .. 6 ft. 0 in.

(10) Minimum horizontal distance from edge of any platform to a pillar, column, lamp, or similar isolated structure within a height of 14 ft. 6 in. from rail level .. 6 ft. 0 in.

Note.—(*a*) It is desirable that items (7), (8), (9) and (10) shall be increased by at least 9 in. so that the distances from centre of a straight track may be 24 ft. 3 in., 18 ft. 3 in., 12 ft. 3 in., and 12 ft. 3 in. respectively or that the distance from the centre of track alongside a platform to the next adjoining track or structure be increased by 9 inches.

(*b*) Items (7), (8), (9) and (10) apply to buildings and isolated structures, not readily removable,

erected on ground over which it is anticipated that a platform may be extended in the future.

(*c*) A pillar or column which covers more than 4 square feet in plan, must be classed as a "building" and not as an "isolated structure."

(*d*) A ramp or staircase of an overbridge must also be classed as a "building." Infringements of dimensions (7) and (8) will usually be sanctioned for any particular ramp or staircase if recommended by the Government Inspector.

(*e*) Item (10) applies to packages and parcels lying on a platform.

(11) Minimum horizontal distance from centre of track to any structure, which is not a platform, from rail level to 1 foot above rail level .. .. .. **6 ft. 3 in.**

NOTE.—(*a*) Signal wires or supports for signal wires may be allowed 6 ft. 0 in. from centre of track provided they are not more than 6 in. above rail level.

(*b*) To the above minimum horizontal distance must be added allowance for curves according to column 4 or 8 of the Appendix.

(12) Minimum horizontal distance from centre of track alongside a passenger platform to any structure facing the platform or less than 100 ft. beyond the end of the platform, from 1 foot above rail level to 14 ft. 6 in. above rail level .. .. .. 9 ft. 0 in.

NOTE.—(*a*) This rule does not apply to a water crane, standard of overhead watering arrangements, point lever, signal post and standard of signal bridges between tracks, the 9ft. in these cases becoming the 7 ft. 0 in. of Items (13) and (14) below; nor does it apply to a loading gauge.

(*b*) Where the structure is on the inside of a curve, an extra width must be allowed as shown in columns 5 to 7 of the Appendix. Where the structure is on the outside of a curve, an extra width must be allowed as shown in column 8 of the Appendix.

(13) Minimum horizontal distance from centre of track to any part of a water column, standard, signal or point lever, from 1 foot above rail level to 14 ft. 6 in. above rail level .. .. .. 7 ft. 0 in.

NOTE.—For extra allowance on curves, see note (*b*) to item (12).

(14) Minimum horizontal distance from centre of track to any structure not in the vicinity of a passenger platform, and not on a goods platform, from 1 foot above rail level to 14 ft. 6 in. above rail level .. .. .. 7 ft. 0 in.

NOTE.—(*a*) Coal or any material stacked by the side of any track is to be considered a structure in the sense in which the word is here used.

(*b*) For extra allowance on curves, see note (*b*) to item (12).

(15) Minimum height above rail level, for a width of 4 ft. 6 in. from centre of track, of tie-rods or underside of any continuous covering in a passenger station 20 ft. 0 in.

NOTE.—(*a*) This does not apply to overhead piping parallel to the track.

(*b*) A projecting overhanging roof is permissible in the case of a goods shed on a siding, if it does not infringe the outline of the figure for minimum fixed structures out of stations.

(16) Minimum height above rail level, at centre of track, for foot bridge or other over-bridge crossing the line in stations .. .. 16 ft. 6 in.

Points and Crossings—

(17) Maximum height above rail level of any part of interlocking or signal gear from centre line to 6 ft. 3 in. from centre line .. 2½ in.

NOTE.—(*a*) Metal ramps should be provided over all interlocking gear projecting above rail level between rails to prevent hanging couplings catching in the gear;

(*b*) For signal wires or supports, see note (*a*) to item (11).

(18) Minimum horizontal distance from centre of track to point handle, indicator or any part of point apparatus from 2½ in. above rail level to 1 foot above rail level .. .. .. 6 ft. 3 in.

NOTE.—(*a*) A point handle may not, in any position, be within 6 ft. 3 in. of the centre line of nearest track; a clear distance of 6 ft. 3 in. is also to be preserved from centre of nearest track to any part of the point apparatus, fixed or moveable,

more than $2\frac{1}{2}$ inches above rail level. An arrangement involving the placing of a point handle between tracks should be avoided so far as practicable.

(*b*) On curves, the distance must be increased by the amount shown in column 4 or 8 of the Appendix.

(19) Maximum clearance of check rail opposite nose of crossing and at heel of switch rail .. $1\frac{7}{8}$ in.

(19a) Minimum clearance of check rail opposite nose of crossing and at heel of switch rail. .. $1\frac{3}{4}$ in.

(19b) Maximum clearance of wing rail at nose of crossing .. .. $1\frac{7}{8}$ in.

(19c) Minimum clearance of wing rail at nose of crossing .. .. $1\frac{3}{4}$ in.

(20) Minimum clearance between toe of open switch and stock rail .. .. $4\frac{1}{2}$ in.

(21) Minimum depth of space below rail level for wheel flange .. $1\frac{1}{2}$ in.

(22) Minimum radius of curve for slip points, turnouts or crossover roads .. .. 800 ft.

NOTE.—This may be reduced to the proper radius for a turnout from

the straight with a 1 in 8½ crossing, the curve being tangential to the switch rail and a short length of straight at the crossing.

(23) Minimum angle of crossing (ordinary) .. .. .. 1 in 12.

Note.—Crossing as sharp as 1 in 16 will usually be sanctioned if recommended by the Government Inspector.

(24) Diamond crossing not to be flatter than .. .. .. 1 in 10

(25) Minimum length of tongue rail 12 ft.

(26) Minimum length of train protection, point locking or fouling treadle bar .. .. .. 42 ft.

Note.—There must be no change of super-elevation (of outer over inner rail) between points 60 ft. outside toe of switch and nose of crossing respectively.

III. M.—WORKSHOP AND STATION MACHINERY.

Water Tanks and Water Cranes—

(1) Minimum distance from centre of track to face of tank-house less than 100 ft. beyond the end of a passenger platform .. .. 18 ft. 0 in.

(2) Minimum horizontal distance from centre of track to any part of water column from 1 foot above rail level to 14 ft. 6 in. above rail level .. .. .. 7 ft. 0 in.

NOTE.—For extra allowance on curves, see note (*b*) to item 12 of Chapter II. M.

(3), (4), (5) & (6): see items (3), (4), (5) & (6) of Chapter III R, of the Schedule of recommended Dimensions.

Ash-pits, etc.—

(7) Average depth for ash-pits in station yards and for carriage-examining pits .. .. .. 2 ft. 6 in.

Running Sheds and Workshops—

(8) Minimum distance centre to centre of tracks .. .. .. 14 ft. 0 in.

(9)	Minimum clear distance from centre of track to any isolated structure, such as a pillar ..	6 ft. 6 in.
(10)	Minimum clear distance, for a height of 6 ft. above rail level, from centre of track to any continuous structure	9 ft. 0 in.
(11)	Minimum height above rail level to tie-bars, girders, etc. ..	16 ft. 6 in.
(12)	Minimum height of doorways, if flat at top	16 ft. 6 in.
(13)	Average depth for pits in running Sheds	2 ft. 6 in.

IV. M.—ROLLING STOCK.

Maximum moving dimensions—

Maximum width over all projections—

(1)	At 4 inches above rail level when fully loaded	8 ft. 0 in.
(2)	At 1 foot above rail level when fully loaded	10 ft. 0 in.
(3)	From 1 foot above rail level when fully loaded to 3 ft. 9 in. above rail level when fully loaded	10 ft. 0 in.
(4)	From 3 ft. 9 in. above rail level when fully loaded to a height of 11 ft. 6 in. above rail level when empty :—	
	(*i*) for bogie vehicles	10 ft. 0 in.
	(*ii*) for four-wheeled vehicles ..	10 ft. 6 in.

NOTE.—In the case of bogie vehicle an over-all width of 10 ft. 6 in. may be allowed over hand rails, door handles and lamps from a height of 4 ft. to a height of 7 ft. 6 in. above rail level.

Maximum width over open doors, including all projections—

(5)	for passenger vehicle	13 ft. 3 in.

(6) for goods vehicle .. .. 14 ft. 0 in.

NOTE.—Doors of horse boxes, brake-vans, luggage vans and rising and falling flap doors of goods wagons are exempted from this rule.

Maximum height above rail level—

(7) At centre of unloaded vehicle .. 13 ft. 6 in.

(8) At sides of unloaded vehicle 10 ft. 6 in. wide .. .. .. 11 ft. 6 in.

(8a) At sides of unloaded vehicle 10 ft. 0 in. wide .. .. .. 11 ft. 7⅛ in.

(9) Minimum height above rail level when fully loaded for a width of 4 ft. 0 in. from centre of track .. 4 in.

(10) Minimum height above rail level when fully loaded at 5 ft. from centre of track .. .. 12 in.

Loading gauge for goods—

(11) Maximum width .. .. 10 ft. 8 in.

(12) Maximum height above rail level at centre .. .. .. 13 ft. 7 in.

(13) Maximum height above rail level at sides .. .. .. 11 ft. 7 in.

NOTE.—The loading gauge is for testing loaded and empty vehicles, the maximum moving dimensions are given in items (4), (7) and (8) above.

Wheel base and length of Vehicle—

(14) Maximum rigid wheel base for four-wheeled vehicle .. .. 20 ft. 0 in.

(15) Minimum distance apart of bogie centres for bogie vehicle .. ⅗ of length of body of vehicle.

(16) Maximum distance apart of bogie centres for bogie vehicle .. 48 ft. 0 in.

(17) Minimum rigid wheel base for bogie vehicle .. .. .. 8 ft. 0 in.

(18) Maximum length of body or roof for— ..

(*i*) bogie vehicle .. .. 68 ft.

(*ii*) four-wheeled vehicle .. 28 ft.

(19) Maximum distance apart between any two adjacent axles .. 39 ft.

Wheels and Axles—

(20) Maximum and minimum wheel gauge, or distance apart, for all wheel flanges .. .. .. 5 ft. 3 in.

(21) Maximum and minimum diameter on the tread for new carriage or wagon wheel, measured at 2 in. from wheel-gauge face .. .. 3 ft. 7 in.

(22) Minimum projection for flange of new tyre below rail level, measured at 2 in. from inside of tyre .. .. $1\frac{1}{8}$ in.

(23) Maximum projection for flange of worn tyre below rail level .. $1\frac{3}{8}$ in.

(24) Maximum thickness of flange of tyre measured at $\frac{1}{2}$ in. from outer edge of flange .. .. $1\frac{1}{8}$ in.

(25) Minimum thickness of flange of tyre .. .. $\frac{5}{8}$ in.

(26) Minimum width of tyre—

(i) Locomotive, coupled wheels $5\frac{1}{4}$ in.

(ii) Locomotive, other than coupled .. .. .. 5 in.

(iii) Tender, carriage and wagon 5 in.

(27) Incline of Tread .. .. 1 in 20.

Height of Floors—

(28) Maximum height above rail level for floor of any unloaded vehicle .. .. 4 ft. 5 in.

(29) Minimum height above rail level for floor of fully loaded passenger vehicle .. .. 4 ft. 1 in.

(30) Minimum height above rail level for floor of fully loaded goods vehicle .. .. .. 3 ft. $8\frac{1}{2}$ in.

Buffers and Couplings—

(31) Maximum and minimum distance apart for centres of buffers 6 ft. 5 in.

(32) Maximum height above rail level for centres of buffers for unloaded vehicle .. .. 3 ft. 7½ in.

(33) Minimum height above rail level for centres of buffers for fully loaded vehicle .. .. 3 ft. 1½ in.

Accommodation—

(34) Minimum width of seat per passenger.. .. .. .. 19½ in.

(35) Minimum floor area per passenger .. .. 3½ sq. ft.

(36) Minimum cubic capacity per passenger.. .. .. .. 25 c. ft.

Electrical Standard Dimensions—

Minimum-height from rail level to the underside of a live conductor :—

(*a*) In under-bridges and tunnels .. 16 ft. 6 in.

(*b*) In the open .. .. .. 18 ft. 0 in.

(*c*) Where there is a likelihood of men standing on the top of vehicles. 24 ft. 6 in.

(*d*) At level crossings .. .. 18 ft. 0 in.

(e) The dimensions which fix the amount of variation of the wire either side the centre line also distance between live wire and structures .. .. .. 0 ft 6 in.

41. Standard Dimensions Recommended.

5 FT. 6 IN. GAUGE.

I. R.—GENERAL.

Formation, Single Line—

(1) Minimum width in embankment 20 ft. 0 in.

(2) Minimum width in cutting (*excluding side drains*) .. .. 18 ft. 0 in.

Formation, Double Line—

(3) Minimum width in embankment 35 ft. 6 in.

(4) Minimum width in cutting (*excluding side drains*) .. .. 33 ft. 6 in.

Note.—(a) where the line is on a curve, the width of formation must be increased by the amount shown in column 9 of the Appendix.

Spacing of Tracks—

(5) Minimum distance centre to centre of tracks (outside station limits) .. .. 15 ft. 6 in.

NOTE.—(*a*) The expression "station limits" means the portion of a railway which is under the control of a Station Master and is situated between the outermost signals of the Station *vide* Rule 1 (31), Chapter I, Part I, of the General Rules for Open Lines (1906).

(*b*) where the line is on a curve, the distance between tracks must be increased by the amount shown in column 9 of the Appendix."

Transition approaches to curves—

(6) Length in feet of transition curve when the shift is 2 ft. 8 in. $=8\sqrt{R}$

(7) Alternative formula for length of transition curve in feet .. $=6\times$ permissible speed in miles per hour.

Gradient in Station—

(8) Maximum gradient in station yard 1 in 1000

NOTE.—(*a*) It is very desirable that the gradient in a station yard should be kept as flat as possible. Except where great expense is involved it should not be made steeper than 1 in 1000.

(*b*) Hump or gravity yards are exempted from this rule.

Ballast—

(9) Width of ballast at level of foot of rail .. .. 11 ft. 0 in.

(10) Depth of ballast below sleepers 8 in.

Sleepers—

(12) Minimum number of cross sleepers per mile .. .. 2112.

NOTE.—12 sleepers per 30 feet rail=2112 sleepers per mile. 15 sleepers per 36 feet rail=2,200 sleepers per mile.

Buildings and Structures—

(17) Minimum horizontal distance, from centre of track to any structure, except a platform, from 1 foot above rail level to 14 ft. 6 in. above rail level .. .. .. 7 ft. 9 in.

(18) Height above rail level, for a width of 3 feet, each side of centre of track, for over-bridges or over head bracing out of stations. 17 ft. 0 in.

NOTE.—For additions to items (17) and (18) on curves, see columns 5 to 8 of the Appendix.

(19) Minimum height above rail level for telegraph wires crossing the line .. .. .. 22 ft. 6 in

Tunnels, Single Line—

(22) Minimum height above rail level at centre .. .. .. 21 ft. 6 in.

(23) Minimum width at rail level . 14 ft. 6 in.

(24) Minimum width from 1 foot above rail level to 14 ft. 6 in. above rail level .. .. 16 ft. 0 in.

(25) Minimum width at 17 ft. 0 in. above rail level .. .. .. 6 ft. 0 in.

NOTE.—Where the line is on a curve, the width of the tunnel must be increased—

(*i*) On the outside of the curve, by the amount shown in column 8 of the Appendix.

(*ii*) On the inside of the curve, by the amount shown in column 4 or 7 of the Appendix.

Tunnels, Double Line—

(26) Minimum height above rail level at centre .. .. .. 22 ft. 6 in.

(27) Minimum width at rail level .. 30 ft. 0 in.

(28) Minimum width from 1 foot above rail level to 14 ft. 6 in. above rail level .. .. .. 31 ft. 6 in.

(29) Minimum width at 17 ft. 0 in. above rail level .. .. .. 21 ft. 6 in.

NOTE.—(*a*) Where the line is on a curve, the width of the tunnel must be increased by the amounts shown in the note to items (23), (24) and (25) above, *plus* the extra allowance between tracks shown in column 9 of the Appendix.

(*b*) The above items for single and double line tunnels are strongly recommended for use on all lines as the cost of any subsequent enlargement of tunnel section is prohibitive.

II. R.—STATION YARDS.

NOTE.—The expressions "in stations" and "out of stations" are to be interpreted in accordance with the definition of "Station limits" given in Rule I (31), Chapter I, Part I, of the General Rules for Open lines, 1906, *viz.*, "Station limits" means the portion of a railway which is under the control of a Station Master and is situated between the outermost signals of the Station.

Spacing of Tracks—

(1) Minimum distance centre to centre of tracks . .. .. 15 ft. 6 in.

NOTE.—(*a*) Where the line is on a curve, the distance must be increased by the amount shown in column 9 of the Appendix.

(*b*) Where it is necessary to place a water column, signal post or overbridge standard, etc., between the tracks, the distance must, if necessary, be increased to comply with items (12), (13) and (14) below and the notes appended thereto.

Platforms—

(2) Minimum length of passenger platform .. .. 800 ft.

Buildings and Structures—

(7) Minimum horizontal distance *from centre of track* to any building or longitudinal boundary fence on a passenger platform which is not an island platform .. .. .. 30 ft. 0 in.

NOTE.—For the return end of platform fencing this item may be reduced to 3 ft. 6 in. from edge of platform.

(8) Minimum horizontal distance *from centre of track* to any building on an island passenger platform .. .. 18 ft. 3 in.

(9) Minimum horizontal distance from centre of track to any building on a goods platform .. 16 ft. 3 in.

(10) Minimum horizontal distance *from centre of track* to a pillar, column, lamp, or similar isolated structure on any platform within a height of 14 ft. 6 in. from rail level .. .. 16 ft. 3 in.

NOTE.—(*a*) For additions to items (7), (8), (9) and (10) see columns 4 to 8 of the Appendix. Distances from edge of a straight

platform corresponding to the above items are 24 ft. 6 in., 12 ft. 9 in., 10 ft. 9 in., and 10 ft. 9 in., respectively.

(*b*) Items (7), (8), (9) and (10) apply to buildings and isolated structures, not readily removeable, erected on ground over which it is anticipated that a platform may be extended in the future.

(*c*) A pillar or column which covers more than 4 square feet in plan, must be classed as a "building" and not as an "isolated structure."

(*d*) A ramp or staircase of an overbridge must also be classed as a "building."

(12) Minimum horizontal distance from centre of track alongside a passenger platform to any structure facing the platform or less than 100 ft. beyond the end of the platform, from 1 foot above rail level to 14 ft. 6 in. above rail level .. .. .. **10 ft. 0 in.**

NOTE.—(*a*) This rule does not apply to a water crane, standard of overhead watering arrangements, pole of electric transmission line, point lever, signal post and standard

of signal bridges between tracks, the 10 ft. in these cases becoming the 7 ft. 9 in. of items (13) and (14) below; nor does it apply to a loading gauge.

(*b*) Where the structure is on the inside of a curve, an extra width must be allowed as shown in columns 4 to 7 of the Appendix. Where the structure is on the outside of a curve, an extra width must be allowed as shown in column 8 of the Appendix.

(13) Minimum horizontal distance from centre of track to any part of water column, standard, signal or point lever from 3 ft. 9 in. above rail level to 14 ft. 6 in. above rail level .. .. .. .7 ft. 9 in.

NOTE.—For extra allowance on curves, see note (*b*) to item (12).

(14) Minimum horizontal distance from centre of track to any structure not in the vicinity of a passenger platform, and not on a goods platform, from 1 foot above rail level to 14 ft. 6 in. above rail level .. .. .. 7 ft. 9 in.

NOTE.—(*a*) This rule does not apply to any part of water column,

standard, signal or point lever from 1 ft. above rail level to 3 ft. 9 in. above rail level, the 7 ft. 9 in. in these cases becoming the 7 ft. of item (14) of Chapter II. M.

(*b*) For extra allowance on curves, see note (*b*) to item (12).

(15) Minimum height above rail level, for a width of 4 ft. 6 in. from centre of track, of tie-rods or underside of any continuous covering in a passenger station. 22 ft. 6 in.

NOTE.—(*a*) This does not apply to overhead water piping parallel to the track.

(*b*) A projecting overhanging roof is permissible in the case of a goods shed on a siding, if it does not infringe the outline of the figure recommended for minimum fixed structures out of stations.

(16) Minimum height above rail level, at centre of track, for foot bridge or other over-bridge crossing the line in stations .. 19 ft. 0 in.

Points and Crossings—

(23) Angle of Crossing to be used in turnout and crossover run over by a passenger train .. .. 1 in 12.

III. R.—WORKSHOPS AND STATION MACHINERY.

Water Tanks and Water Cranes—

(1) Distance from centre of track to face of tankhouse when less than 100 ft. beyond the end of a passenger platform .. .. 30 ft. 0 in.

(2) Minimum horizontal distance from centre of track to any part of water column from 1 foot above rail level to 14 ft. 6 in. above rail level .. .. .. 7 ft. 9 in.

Note.—For extra allowance on curves, see note (*b*) to item (12) of Chapter II. M.

(3) Minimum height for bottom of tank above rail level at water column— .. ..

(*a*) for watering engine .. 25 ft. 0 in.

(*b*) for washing out engine .. 40 ft. 0 in.

(4) Minimum total tank capacity at any station .. .. .. 2,000 c. ft. or 12,500 gallons.

(5) Minimum height above rail level for discharge orifice of water crane .. .. 12 ft. 0 in.

(6) Minimum internal diameter for piping from tank to water crane 8 in.

NOTE.—Items No. (3), (4), (5) and (6) are strongly recommended for use on all lines, as experience has shown the utmost importance not only of the provision of an ample supply of water, but also the necessity of ensuring a quick flow into engine tenders. Any failure or delay in water supply is liable to cause serious dislocation to traffic.

Ash-pits, etc.—

(7) Minimum clear length at bottom for ash-pit .. .. .. 65 ft. 0 in.

Engine Running Sheds —

(8) Minimum distance centre to centre of tracks .. .. .. 18 ft. 9 in.

(9) Minimum clear distance from centre of track to any isolated structure, such as a pillar .. 8 ft. 3 in.

(10) Minimum clear distance, for a height of 6 ft. above rail level, from centre of track to any continuous structure .. .. 10 ft. 9 in.

(11) Minimum height above rail level to tie-bars, girders, etc. .. 18 ft. 0 in.

Workshops–

(8) Minimum distance centre to centre of tracks .. .. .. 15 ft. 0 in.

(9) Minimum clear distance from centre of track to any isolated structure such as a pillar .. 7 ft. 6 in.

(10) Minimum height above rail level to tie bars, girders, etc. .. 17 ft. 9 in.

APPENDIX.

45. *Extra Clearances on Curves.*

Degree of curve.	Radius of curve.	Super-elevation.	EXTRA CLEARANCE BETWEEN STRUCTURE AND ADJACENT TRACK. Inside of curve: Rail level to 1 foot above.	Inside of curve: 2′ 9″ platform.	Inside of curve: 3′ 6″ platform.	Inside of curve: Any height above 3′ 6″	Outside of curve: Any height.	Extra clearance between tracks.
1	2	3	4	5	6	7	8	9
	Feet.	In.	In.	In.	In.	In.	In.	In.
1°	5,730	1	1	1	1	3	5	6
2°	2,865	2	2	2	3	6	5	8
3°	1,910	3	3	4	4	9	6	10
4°	1,432	4	3	5	6	12	6	11
5°	1,146	5	4	6	7	16	7	13
6°	955	6	5	7	8	19	8	15
7°	819	6	6	8	9	20	8	16
8°	716	6	6	9	10	21	9	18
9°	637	6	7	9	10	22	10	19
10°	573	6	8	10	11	22	10	20

NOTE.—(*a*) The clearances are calculated for the degree of curvature and super-elevation shown in the Table and are to be adopted for these and any less super-elevations.

(*b*) Column 3 has been calculated for a speed of 36 miles an hour.

Note on extra Clearance on Curves culled from the Schedule of Standard Dimensions, 5′ 6″ Gauge, 1922.

Note on extra Clearance on Curves—

1. It has been contended that the extra clearances prescribed in the Appendix to the Schedule of Dimensions of 1913 for 5 ft. 6 in. Gauge are too liberal.

2. The contention is based on the assumption that extra clearances on curves are required only because a vehicle standing on a curve lies along a chord of the curve, so that its ends overhang the outside of the curve and its middle overhangs the inside of the curve.

Extra clearances are, however, also required on account of the effect of "super-elevation of outer over inner rail" and on account of the "lurch" of a moving vehicle.

(*a*) *Curvature—*

3. The extra clearance required on the inside of a curve, on account of a vehicle lying along a chord of the curve, is the versine of a chord equal in length to the distance between the bogie-truck centres.

4. The extra clearance required on the outside of a curve is the difference between the versines

of two chords equal in length to :—

(1) the over-all length of the bogie vehicle, and

(2) the length between the bogie-truck centres.

5. Formula for versine :—

if V=versine in feet,

R=radius of curve in feet and

C=length of chord in feet,

then $V=\frac{C^2}{8R}$ in feet.

6. The distance between the bogie-truck centres of the longest bogie vehicles in use at present is 48 feet. The maximum over-all length of bogie vehicle bodies is 68 feet.

7. If the versines V and v for 68 ft. and 48 ft. chords are calculated, it will be found that V=2v near enough for all practical purposes.

(*b*) *Super-elevation*—

8. Superelevation tends to tilt a vehicle towards the inside of the curve and therefore to reduce the distance between the vehicle and a fixed structure inside the curve. The reduction varies from nothing at rail level to a maximum at the eaves of the vehicles.

9. Formula for Super-elevation allowance :—

if S = reduction of clearance, between vehicles and fixed structure, due to super-elevation,

h = height of point of vehicle under consideration above rail level,

s = super-elevation of outer over inner rail, and

g = gauge of track,

then $S = h \times \frac{s}{g}$.

Combined effect of Curvature and Super-elevation—

10. To provide for a vehicle at rest on a curved track alongside a fixed structure we must provide extra clearances as follows :—

$v+S$ on the inside of the curve in case the full amount of super-elevation is allowed, and

v on the outside of the curve in case there is no super-elevation.

(c) Lurch—

11. A vehicle moving round a curve is liable to *lurch* on account of (*i*) play in bolsters, (*ii*) compression and extension of springs due to centrifugal tendency, and (*iii*) unevenness of track.

A few measurements of *lurch* were recorded during experiments with long bogie vehicles on Indian railways in 1908 but they were not numerous enough to settle a reliable formula which would cover all conditions.

It is believed that the figures in the Appendix to the Schedule of 1913 allow for a *lurch* of 4 inches

at the end of a vehicle on the outside of all curves and for a lurch $= \frac{S}{4}$ at the middle of a vehicle on the inside of all curves. These amounts must be accepted until further experiments produce more reliable results.

Lurch also takes place on the straight, experiments are necessary to ascertain the amount of it. The lurches of four inches and $\frac{1}{4}$S on curves are *assumed* to be *additional* to any lurch which occurs on the straight.

Combined effect of Curvature, Super-elevation and Lurch—

12. The total extra clearances to be provided between a vehicle and a fixed structure are therefore :—

$v + 4''$ on the outside of a curve, and

$v + \frac{5}{4}S$ on the inside of a curve.

Extra clearances required between parallel curved tracks—

13. There are four possibilities :—

(1) Two trains at rest on the tracks,

(2) the train on the outer track stationary and the train on the inner track running at speed,

(3) two trains passing one another at speed, and

(4) the train on the inner track stationary and the train on the outer track running at speed.

14. In case (1), assuming equal super-elevation on the two tracks, the extra clearance required on account of the train on the outer track is v + S and the extra clearance required on account of the train on the inner track is v — S: for the end of a vehicle on the inner track may be opposite the middle of a vehicle on the outer track. The total extra clearance is therefore v + v, *i.e.*, 2v or V.

Case (2) is worse than case (1) because we must allow for lurch on the inner train; the extra clearance required is 2 v + 4″, *i.e.*, V + 4″.

Case (3) is possibly not so bad as case (2), but we must allow for the two trains lurching in opposite directions and therefore provide extra clearance amounting to V + 4″ + $\frac{1}{4}$S if both tracks have the same super-elevation.

Case (4) is not so bad as (3) because the stationary train will not lurch.

So the worst possible case is case (3) and the clearance required is not less than V + $\frac{1}{4}$S + 4″.

Summary—

15. The various columns in the Appendix Table are therefore calculated from the following formula:—

Columns 4, 5, 6 and 7 from the formula $v + S$.
Column 8 „ „ „ $v + 4''$.
Column 9 „ „ „ $V + \frac{1}{4}S + 4''$

where V = "versine" of a 68 ft. chord $\frac{68 \times 68}{8 \times \text{radius}} \times 12$ in.

v = "versine" of a 48 ft. chord = $\frac{48 \times 48}{8 \times \text{radius}} \times 12$ in.

$$S = \frac{h \times (\text{Super-elevation according to column 3})}{5\frac{1}{2}} \text{ in.}$$

and h is 1 for column 4.
$2\frac{3}{4}$ for column 5.
$3\frac{1}{2}$ for column 6, and
11 or 14 less 3″ } whichever is greater for columns 7 and 9.

For curves over 3° the additional clearance to be provided between a vehicle and a fixed structure on the inside of a curve is greater than the additional clearance required between parallel curved tracks having the same curvature and super-elevation.

If a signal post or water column be fixed between tracks on a curve the extra allowance will be the thickness of the obstruction *plus* the sum of the figures given in columns 7 and 8 unless the obstruction is canted at the same angle as the super-elevation of the tracks.

16. The figures in columns 4 to 8 are about the same as the corresponding figures of the Schedule of 1913 even though they provide for the increase due to vehicles with eaves 14 ft. (less 3 in.) instead of 11 ft. 6 in. high and no reduction made for the allowance for *lurch* already provided for on the straight.

The figures in column 9 only apply to extra clearances between tracks which have no obstruction between them. They are smaller than the corresponding figures of the Schedule of 1913 as no allowance was made in 1913 for the super-elevation of the inner track. The figures in column 9 are equal to the sum of the figures in columns 7 and 8 less the displacement due to super-elevation.

17. The allowances in the Table are probably in excess of actuals especially in station yards where speeds are low and smaller super-elevation provided. It is however not considered desirable to reduce the allowances until further experiments under all conditions have been made. In special cases where space is not available or the expenditure unduly heavy sanction should be obtained for any infringement.

INDEX.

III. Preface to the First Edition.

1. There are so many authoritative books on Points and Crossings, that an apology is needed for presuming to add one more to their number. When learning the theory of points and crossing work, I strongly felt that although there is a large number of books on Points and Crossings, some quite admirable in their way, a hand-book was yet wanting which would treat only of points and crossings in a simple way. Most of the existing works present the theoretical side of the subject which very advanced students will only understand. An attempt has therefore been made in this small book to treat the subject in the simplest way possible. Though this book has been written for the use of beginners, it is hoped that it may also prove of some service to those of ripe experience in constructing new tracks. The book contains rules and formulæ with examples fully worked out in every case. My sole endeavour has been to give Amateur Permanent Way Inspectors a short and concise book which will thoroughly cover their work so far as the points and crossings are concerned.

2. In the preparation of this book, I have received valuable assistance from several books, especially Cole's "Notes on Permanent Way Material and Plate-laying" and Naben's "Notes on Railroading" for which I am indebted to those authors.

3. All suggestions will be most thankfully received.

K. N. SALKADE.